A 20-YEAR-OLD PLANTATION OF HARDY CATALPA, SOUTHERN IOWA.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF FORESTRY—BULLETIN NO. 37.

GIFFORD PINCHOT, Forester.

THE HARDY CATALPA.

I. THE HARDY CATALPA IN COMMERCIAL PLANTATIONS,

By William L. Hall,

Superintendent of Tree Planting.

II. THE DISEASES OF THE HARDY CATALPA,

By Hermann von Schrenk,

Pathologist in Charge Mississippi Valley Laboratory,

Bureau of Plant Industry.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Forestry,
Washington, D. C., June 16, 1902.

Sir: I have the honor to transmit herewith a report entitled "The Hardy Catalpa in Commercial Plantations," by William L. Hall, superintendent of tree planting in the Bureau of Forestry, accompanied by a discussion of "The Diseases of the Hardy Catalpa," by Dr. Hermann von Schrenk, pathologist in charge of the Mississippi Valley laboratory of the Bureau of Plant Industry, and to recommend the publication of the two papers as Bulletin No. 37 of the Bureau of Forestry.

These papers present the results of careful investigations made in the largest planted forests of Hardy Catalpa in this country, and contain an account of the behavior and requirements of this species when grown in close stand in commercial plantations.

Respectfully,

Gifford Pinchot, *Forester.*

Hon. James Wilson, *Secretary.*

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THE HARDY CATALPA.

I. THE HARDY CATALPA IN COMMERCIAL PLANTATIONS,

By William L. Hall,
Superintendent of Tree Planting.

INTRODUCTION.

Forest planting on the prairies west of the Mississippi River began with the earliest settlers. To plant trees for protection from sun and wind seemed one of the first and most important things to be done, and with the building of a house and the breaking up of a garden patch it formed a part of the settler's first summer's work. Each year thereafter, as time and means permitted, the plantation was increased. Scarcely a decade passed before extensive groves for the general purposes of shelter and ornament appeared on almost every farm. The success of these proved that the want of the natural forest could in part be supplied by planted timber.

The growing of forest trees for other farm needs, such as fuel, posts, and poles, was also practiced by many settlers, for the prices of these materials were extremely high in the districts far from the natural forest. The idea of growing posts and poles to sell, however, did not meet with approval for a number of years. It was too long an investment to be attractive in a country just settled. About twenty-five years ago a few men, impressed with the prevailing high prices of such materials and believing it possible to produce them in plantations within fifteen or twenty years, began to plant timber as an investment. Their example encouraged others to plant for the same purpose, and as a result of the work there are now in the Middle West quite a large number of commercial plantations, in some of which the marketing of products has already begun.

Of the trees used for commercial planting none have been planted more extensively in the region of southern Iowa and Nebraska and eastern Kansas than the Hardy Catalpa. In its native habitat along the Lower Wabash and Ohio rivers this tree nearly a century ago gained a reputation for rapid growth and durability. A few years' trial on the plains sufficed to prove its good qualities for that region. It was easily propagated, grew rapidly on prairie soil, had good form, was drought resistant, had few insect or fungous enemies,

and above all was a lasting timber, adapted to many uses. Such good qualities soon brought it into general recognition. In the regions named it took the lead as a commercial tree, especially for such purposes as fence posts, telegraph and telephone poles, and railroad ties.

Its value for most of these purposes has been quite fully demonstrated. As a post timber it has given excellent satisfaction. It ranks with Black Locust and Osage Orange in durability, while it surpasses them in rate of growth, form, penetrability, and freedom from checking. Altogether, as a post timber suitable for growing in a large section of the Middle West it has no equal. For telegraph and telephone poles its only deficiency seems to be a tendency toward crookedness, but possibly this can be overcome by special treatment. A discussion of the subiect is included in this report. As a railroad-tie timber the Hardy Catalpa has not had sufficient trial to demonstrate what its rank should be. Experiments have left no doubt as to its resistance to decay. The only question lies in its resistance to wear. So far as tried it does not stand the wear and tear of a railroad track so well as White Oak, especially under heavy traffic. In the Middle West, however, the traffic on many railroads is comparatively light, while the decay of timber is particularly rapid. Under these peculiar conditions Catalpa will probably outlast Oak as a tie timber.

The main commercial plantations of Catalpa are in Iowa, Kansas, and Nebraska. Kansas especially has a number of large and highly successful plantations. In this report four of the oldest and largest plantations of that State have been selected to illustrate the habit and growth of the Hardy Catalpa in artificial forest and to show the value of its products over and above expenses for a definite time. Careful observations, valuation surveys, and stem analyses have been made in these plantations and it is believed that nothing has been omitted that would add to the accuracy of the estimates and conclusions here given.

The study of the Munger plantation was made in full in the summer of 1900, that of the Farlington Forest and Hunnewell plantation partly in 1900, partly in 1901, while that of the Yaggy plantation was made in March, 1902.

THE MUNGER PLANTATION.

This plantation, belonging to Mr. George M. Munger, is located 8 miles north of Eureka, Greenwood County, Kans. The region is traversed by many small, timber-belted streams, which cut deep into the high, upland prairie. The plantation is situated on a slightly undulating upland prairie, 1,100 feet above sea level. The soil is the fertile clay loam characteristic of that region, and varies in depth from 10 to 20 inches, with occasional spots not exceeding 4 or 5 inches. It also

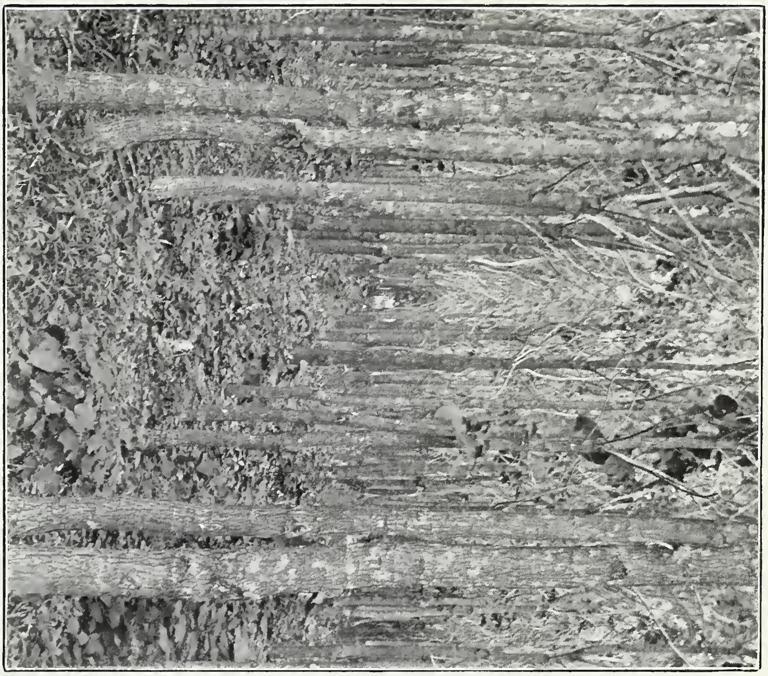

FIG. 1.—GROWTH ON GOOD SOIL, MUNGER PLANTATION.

Perfect undergrowth of shade-enduring weeds.

FIG. 2.—INTERIOR GROWTH, MUNGER PLANTATION.

The inferior trees have been removed and the remaining ones trimmed up.

FIG. 1.—GROWTH ON POOR SOIL, MUNGER PLANTATION.

No leaf cover; light-demanding grasses gaining entrance.

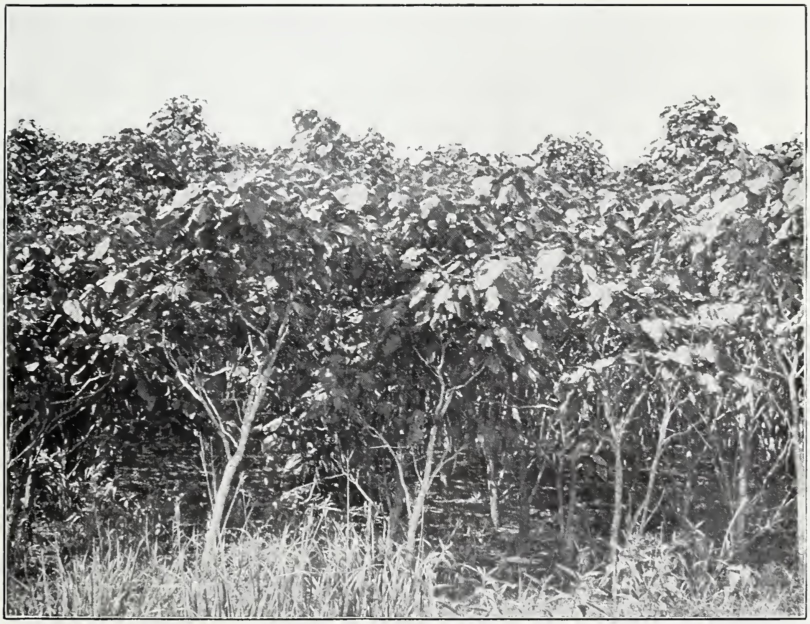

FIG. 2.—GROWTH AT SOUTH EDGE OF MUNGER PLANTATION.

Shows the effect of the wind on the size and form of the trees.

varies in fertility, the deeper soil being of much better quality. Underlying the soil is a very stiff, tenacious clay, from 2 to 4 feet thick, and below this a brittle, yellow clay, containing many small limestone pebbles, and extending to a great depth.

In addition to the extensive use of Green Ash, Black Walnut, and Russian Mulberry in belts, for the protection of orchards, 135 acres of Hardy Catalpa have been planted in a body as a commercial forest. The trees were planted in 1887. They were set in straight rows and spaced accurately 4 by 4 feet. Good cultivation was given, and they grew rapidly. Within three years their tops had formed a perfect canopy, which has since been maintained. The growth has not been even over all the tract, owing to two causes—first, variation in the soil; second, unequal exposure to wind.

Where the soil is deep and rich, the trees have formed straight, long stems with few side branches. On the poor soil they are low, crooked, and much branched. The difference in growth is to be seen by comparing Blocks I and IV in the tables of heights and diameters, and the difference in value is shown in the table of values. (See Pls. I and II.)

The effect of unequal exposure to wind is evidenced by the difference in the growth on the edges of the plantation where exposure is greatest, and on the interior where it is least. The direction of prevailing winds makes the exposure most severe on the south and west sides. But the west side is protected by a tall hedge of Osage Orange, so that here the Catalpas show very little effect of the wind. The south side is entirely unprotected. The hot summer wind, after unobstructed passage over miles of prairie, strikes the trees with most injurious effect.

The broad, delicate leaves of the Catalpa are more easily bruised and torn than those of any other native tree. By early summer the edge rows on the south side of this plantation have fully half their foliage blown or torn off, and it is not regained during the season. The first row on the south showed an average height of but 9 feet, the tenth row 14 feet, and twentieth 21 feet. The effect of exposure is noticeable for 100 feet into the plantation. Not only is the height affected, but the form is likewise injured. Pl. I, fig. 2, shows that the trees have the starved appearance which characterizes their growth on poor soil. A shelter belt of taller trees would have entirely prevented the damage. Even a hedge of Osage Orange like that on the west side of the plantation would have been of great advantage.

LEAF COVER AND UNDERGROWTH.

The mulch of leaves that forms the soil cover varies with the fertility of the soil and the tree growth. Where the soil is rich and the trees large, the mulch is 3 or 4 inches deep, and is matted over the

ground and mingled with dead twigs, as in an ideal forest. On the poor soil the fallen leaves have not formed a mat on the ground, but appear to have been washed or blown away. A few side branches have died. The rest, still alive, remain on the trees with singular persistence. In consequence of this the ground is bare.

On the better soil, where the shade is densest and the leaf mulch best, some undergrowth has appeared. It consists of shade-enduring weeds, shrubs, and trees. There are spots densely covered with White Snake Root (*Eupatorium ageratoides*), which grows to a height of 2 feet and makes a dense shade, while it transpires very little moisture. It makes an excellent ground cover. The volunteer woody growth consists mainly of Mulberry and Dogwood, with some White Elm, Red Cedar, Sumac, and Indian Currant. It is not surprising that the undergrowth is slow in appearing, for the plantation is on the open prairie, several miles from natural timber.

The influence of the shade-enduring undergrowth, whether herbaceous or woody, is altogether beneficial. It serves the same useful end as the undergrowth in the natural forest. When nature thus comes to the assistance of the prairie tree planter and establishes in his plantation the conditions which prevail in the natural forest, the plantation is likely to be perpetuated with little difficulty.

Wholly different is the influence of grasses and weeds which demand light for existence and appear only where sunshine penetrates the scant tree tops and makes their growth possible. These grasses are the enemies of trees and wage relentless warfare with them for possession of the ground. Most of the prairie grasses of the West belong to this class. Such grasses are beginning to appear in the poorer parts of this plantation and will be a constant menace to the trees. (See Pl. II, fig. 1.)

MEASUREMENTS.

Four blocks of one-half acre each (5 by 16 rods) were selected as representing the different classes of growth. Taken together, they give a fair average of the entire forest.

Block I represents the poor growth. There is little soil on this block, the clay lying near the surface. The leaves and litter have been washed or blown away as fast as accumulated, so that the surface is bare. The roots penetrate the clay poorly. The trees are low and scraggy, showing unquestionably an impoverished condition.

Block II was taken with its short side on the exposed south edge. It extends into good timber at the north end and represents a fair average of the entire south side. The soil consists of 8 to 10 inches of good loam covered by 2 inches of leaf mold and underlaid by clay. The tree roots are densely matted in the leaf mold and abundant in the loam, but scarce in the clay. There is little undergrowth.

Block III was selected as an average of the better interior growth. The soil conditions are nearly the same as in Block II, but, being interior, the trees have suffered no damage from wind. There is a good leaf cover on the surface, but no undergrowth.

Block IV represents the thrifty growth near the north side of the plantation. (See Pl. III, fig. 1.) The soil is deeper than on the other blocks and is covered by a good leaf mulch. A scant undergrowth of White Snake Root and Red Mulberry occurs. The trees root deeper on this block than on any of the others.

The following tables show the stand of trees and the height and diameter classes for each of the four blocks:

Heights, Munger plantation.

Block.	Number of trees planted.	Dead or cut out.		Height. Under 15 feet.		From 15 to 19 feet.		From 20 to 24 feet.		25 feet and over.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,365	135	9.9	1,051	77	176	12.9	3	0.2	....	....
II	1,386	360	26	220	15.9	292	21	470	33.9	44	3.2
III	1,407	272	19.3	81	5.8	360	25.6	622	44.2	72	5.1
IV	1,344	162	12	145	10.8	240	17.9	308	22.9	489	36.4
Total	5,502	929	......	1,497	....	1,068	....	1,403	......	605	....
Average	1,375.4	232.25	16.8	374.25	27.375	267	19.35	350.75	25.3	151.25	11.175

Diameters, Munger plantation.

Block.	Number of trees.	Dead or cut out.		Diameter. Under 1 inch.		From 1 to 1.9 inches.		From 2 to 2.9 inches.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,365	135	9.9	2	0.2	151	11.1	626	45.9
II	1,386	360	26	1	.1	56	4	312	22.5
III	1,407	272	19.3	14	1	121	8.6	364	25.9
IV	1,344	162	12	....	....	32	2.4	352	26.2
Total	5,502	929	....	17	....	360	....	1,654	....
Average	137.5	232.25	16.8	4.25	.325	90	6.525	413.5	30.125

Block.	Diameter. From 3 to 3.9 inches.		From 4 to 4.9 inches.		From 5 to 5.9 inches.		From 6 to 6.9 inches.		From 7 to 7.9 inches.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	419	30.7	32	2.2	....	....	....	....	....	....
II	438	31.6	181	13	33	2.4	4	0.3	1	0.1
III	438	31.1	175	12.4	22	1.6	1	.1	....	....
IV	542	40.3	225	16.7	29	2.2	2	.2	....	....
Total	1,837	....	613	....	84	....	7	....	1	....
Average	459.25	33.425	153.25	11.075	21	1.55	1.75	.15	.25	.025

PRODUCTS AND VALUE.

The value of the Catalpa in this region depends upon its usefulness for telegraph poles, posts, and fuel. The trees are not yet old enough to turn out telegraph poles, and consequently must be estimated at their post value. On account of the distance from the natural forest, posts are high in price and very small pieces are acceptable. In selling posts Mr. Munger makes the following grades: Two to 2½ inches, 2½ to 3½, 3½ to 4½. These sell at 5, 7, and 10 cents, respectively. In the measurements any straight stick over 3 and under 6 inches at the butt was called a post and valued at 8 cents, and any straight stick between 2 and 3 inches was called a stake and valued at 5 cents. This is rather lower than Mr. Munger's selling rate, but taking the sizes for the different grades into consideration it does not differ from it greatly. The following table shows the number and value of posts and stakes found on each block:

Products and value of Munger plantation.

Block.	Posts.		Stakes.		Total value.
	Number.	Value.	Number.	Value.	
I	410	$32.80	884	$44.20	$77.00
II	865	69.20	982	49.10	118.30
III	866	69 28	1,177	58.85	128.13
IV	1,402	112.16	1,371	68.55	180.71
Total	3,543	283.44	4,414	220.70	504.14
Average per acre	1,771	141.72	2,207	110.35	252.07

COST AND VALUATION.

The gross value of the timber crop per acre in this plantation is $252.07.

In estimating the cost of the plantation, Mr. Munger states:

Fifty-seven acres were planted in the spring of 1887, the remaining 78 acres in the fall of the same year. The trees for the first 57 acres were bought of Robert Douglas, of Waukegan, Ill., and cost, with freight added, about $4 per thousand. The trees for the 78 acres were grown by myself on the farm, and the cost I estimate to be not more than 50 cents per thousand. The cost of planting per acre was about $3.

The trees were cultivated all the first season (probably about six times) and to the first of July the second year (probably about three times). The cost of same I estimate to be about $2.50 per acre.

There was no further outlay.

In making the estimate an annual rental of $2 per acre is counted, which is rather high for the region. The expense for an average acre is as follows:

Cost of trees	$5.46
Cost of planting	3.00
Cost of cultivation	2.50
Rent of land, thirteen years, at $2	26.00
Cost of marketing (estimated)	20.00
Total	56.96

If the total cost be taken from the gross value a difference of $195.11 is obtained, which represents the return on the investment. This amounts to a net annual acreage return of $15.01. Allowing 6 per cent compound interest on the investment there is still a profit per acre of $167.01.

Mr. Munger began selling posts from the plantation about four years ago, and finds ready sale on the local market for all he has to offer. He states that at times he has been able to estimate the posts by the cord, and discovered that he was receiving about $20 per cord for the product. By the estimate here given very nearly this price is received. The waste product makes fuel of exceptional value and can often be sold at considerable profit, but on account of the difficulty of estimating the quantity in the standing timber and the uncertainty of sale no value is given it in this estimate.

METHODS OF TREATMENT.

The plantation is now at the stage where some treatment is required to give opportunity for future growth. In the poorer parts the trees are not making much growth. In the better parts the dense crowding has produced long poles with but few living branches. The trees swaying in the wind strike against one another and tear the foliage so much that in late summer much of it drops off. Sunshine is admitted and opportunity given for the growth of injurious grasses.

Three methods of treatment have been used experimentally on small areas, as follows:

(1) Removing occasional trees (the large ones).

(2) Removing the small trees and trimming up the large ones.

(3) Clean cutting by strips.

The first method looks to present rather than future returns. To take out the large trees leaves more space for those remaining, but it also leaves trees that may be too much impoverished to take advantage of the increase of space, and thereby allow grass to enter. Usually this method will result only in the rapid deterioration of the forest. However, where, on account of poor form, a large tree is fit only for posts or fuel, it should be taken out in order to give room to better shaped, though perhaps smaller, trees.

The second method is applicable when there is a large percentage of well-formed trees of proper height for telegraph poles. The removal of the small and defective trees, if accompanied by the pruning of side branches from those that remain, will result in a few years in poles perfect in form and free from knots. (See Pl. I, fig. 1.) From the stumps of the removed trees will spring up bunches of sprouts which will serve a most useful purpose as undergrowth.

On poor soil, where the trees have made but low growth and can never become better, it is advisable to remove the entire stand by strips, in the hope that by proper treatment of the stump sprouts, trees of superior form may be obtained. Perfect reproduction by sprouts can be depended upon, and experience in other plantations shows that the character of the growth can be greatly improved. This is more fully discussed in connection with the Yaggy plantation. This method of treatment also insures shade for the ground. The stump sprouts will form a dense mass before the first summer is past (see Pl. III, fig. 2), and if most of them are pruned off they are abundant enough to form a heavy mulch on the ground until the sprouts left standing have tops sufficiently large to shade the ground.

Shade for the ground is essential. The admission of light means the entrance of grass, and this, if not corrected, will mark the certain decline of the forest. As the plantation is now at the stage where treatment is necessary, it is extremely important that the methods adopted provide some undergrowth for the protection of the ground. To underplant with other kinds of trees would be too expensive. Unquestionably the most practicable way is to make use of the stump sprouts.

The object of cutting by strips is to make the strips which are left uncut serve as windbreaks for the tender young sprouts. The strips should run east and west, and an uncut strip of four or five rows will be sufficient to protect fifteen or twenty rows of sprouts. Two or three years later the strips left standing in the first place may be removed. (Pl. IV.)

PLANTATIONS IN CRAWFORD COUNTY.

Two of the largest plantations of Hardy Catalpa in the United States are located in Crawford County, Kans. Both were established between 1877 and 1884 and together cover nearly 2 sections of land. One was planted by the Kansas City, Fort Scott and Memphis Railroad Company, and the other by Mr. H. H. Hunnewell, at that time president of the above road. Both plantations were purely commercial in purpose and have for their object the production of posts, telegraph poles, and railroad ties. Together they afford the best opportunity to study the Hardy Catalpa under artificial forest conditions to be found in the United States.

THE FARLINGTON FOREST.[a]

This plantation, established by the Kansas City, Fort Scott and Memphis Railroad Company, is located one-half mile west of the station of Farlington, and occupies an entire section of land, inclusive of a number of swales and ravines not planted. The land consists of undulating upland prairie with a general southeast slope and numerous ravines, forming a complete drainage system. The soil is a moderately fertile loam which overlies a rather tenacious clay subsoil of indefinite thickness.

Four hundred acres were pure planted to Hardy Catalpa, 100 acres to Ailanthus, and nearly 40 acres to Osage Orange, White Ash, Black Walnut, Black Cherry, and Common Catalpa. Only the Hardy Catalpa and Osage Orange have been successful, the location being unadapted to the other species.

The company began planting Hardy Catalpa in 1877 by setting trees on 45 acres. In the spring of 1879 a contract was let to Robert Douglas & Sons, Waukegan, Ill., to plant the remainder of the section. Under the contract Robert Douglas & Sons were to receive $30 per acre for planting the trees and cultivating them until they reached a height of 6 feet. They were to be planted 4 by 4 feet, and a stand of 2,000 per acre was guaranteed. The contract planting began in the fall of 1879, when 75 acres were set. Twenty-five acres were planted in the spring of 1880, 125 acres in the spring of 1881, and over 100 acres in the spring of 1882.

CULTIVATION AND MANAGEMENT.

The trees were cultivated in the manner of a corn crop, three or four cultivations being given during the season. Within two years after planting most of them had reached the height specified in the contract and had passed out of the care of the contractors. As the trees on the poorer soil did not reach the required size in that time, they were cultivated during the third season.

By 1885 the terms of the planting contract were fulfilled. Thenceforth the plantation was managed by the railroad company. Aside from the plowing of fireguards no further work was done until the winter of 1894, when one-fourth of the trees were removed. One tree, usually the most inferior, out of every group of four, was taken, but no removal was made if one or more of the four trees had died. No use was made of the thinnings. The cost of the labor amounted to 62½ cents per acre. This was the last expense incurred in connection with the management of the plantation.

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[a] Now owned and controlled by the St. Louis and San Francisco Railroad Company.

CONDITION OF THE FOREST.

The study of this forest was made during August, 1900. A severe drought prevailing at that time gave exceptional opportunity to study the effect of such conditions as shade, undergrowth, and leaf cover, as well as the defects and needs of the plantation. (Pl. V, fig. 1.)

According to a count on 5 acres in different parts of the plantation. 44 per cent of the trees had been cut or had died. The dead trees are those which had been suppressed and deprived of light beyond endurance. The 56 per cent remaining represents the trees which grew most thriftily. The struggle for existence has been intense. Trees are found in all stages of predominance and suppression, and every year more are dying. On a one-half acre block in the best part of the plantation were found the following dead trees, all of which had been overcome by more vigorous companions:

From 2 to 3 inches diameter	26
From 3 to 4 inches diameter	50
From 4 to 5 inches diameter	11
From 5 to 6 inches diameter	4

By the time the trees were 4 or 5 years old they formed a dense shade. This was preserved until the twelfth year, since which time there has been a gradual thinning of the leaf canopy on account of the death of suppressed trees and side branches, but more particularly on account of the wind, which has opportunity to thrash the tops together and bruise and tear the broad, tender leaves from their first appearance in spring till the end of summer. By midsummer there is often little foliage left. During a normal season the trees on rich and poor soil suffer to nearly the same degree, but drought increases the effect on poor soil. Areas of several acres were destitute of foliage at the time the plantation was studied. Such an admission of light works severe injury to the forest, especially since in many places there is an entire absence of shade-enduring undergrowth. The sunshine permits injurious grasses to steal in and begin a struggle with the trees for possession of the ground. In some places this struggle is now on. There can be but one result—the triumph of the grass. The trees on poor soil have a severe struggle under the best conditions; in competition with grass they have no show whatever.

LEAF COVER AND UNDERGROWTH.

The leaf cover is extremely variable. On the poor soil there is little or none; on the fertile soil there is an abundance. In a small degree the same is true of the undergrowth. In some places there is absolutely none; in other places, and usually on the fertile soil, there is a luxuriant growth, such as shown in Pl. XXIV. As a whole, this plantation, more than any other to which this investigation extended, is characterized by undergrowth. It consists of weeds, with White Snakeroot predominating, and shade-enduring species of

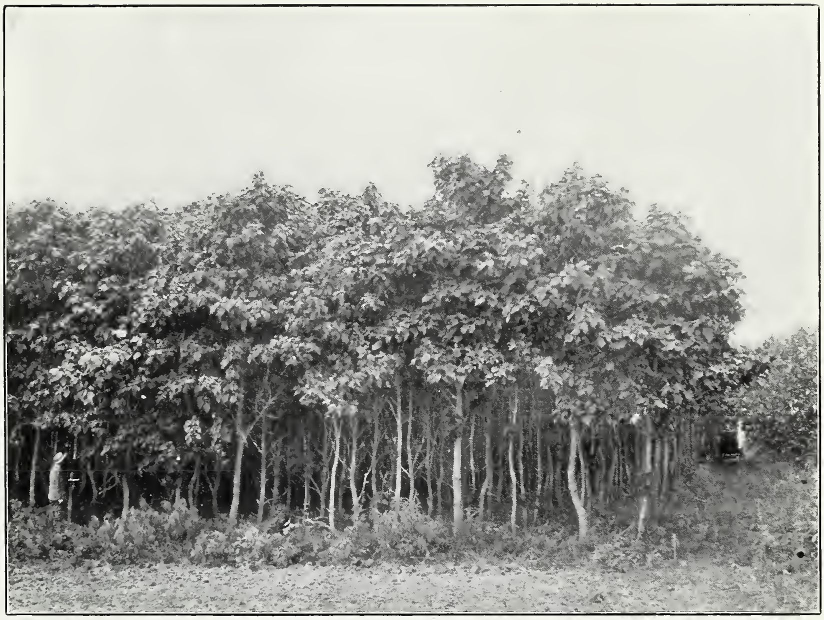

FIG. 1.—NORTHEAST CORNER OF THE MUNGER PLANTATION AND SOME OF THE THRIFTIEST GROWTH.

FIG. 2.—REPRODUCTION ON A CLEAN-CUT STRIP, MUNGER PLANTATION.

STRIP OF TREES LEFT TO PROTECT SPROUTS AFTER CLEAN CUTTING, YAGGY PLANTATION.

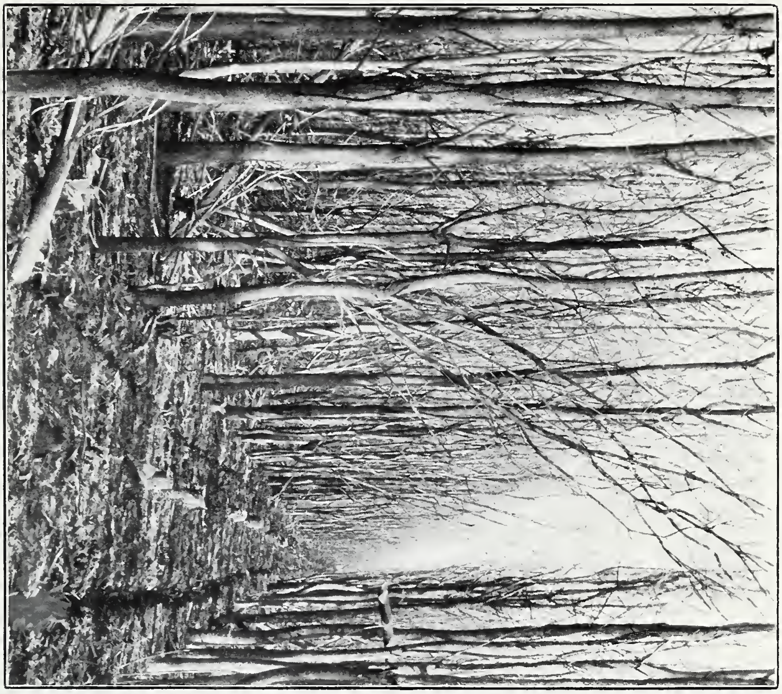

FIG. 1.—FARLINGTON FOREST.

FIG. 2.—THE HUNNEWELL PLANTATION.

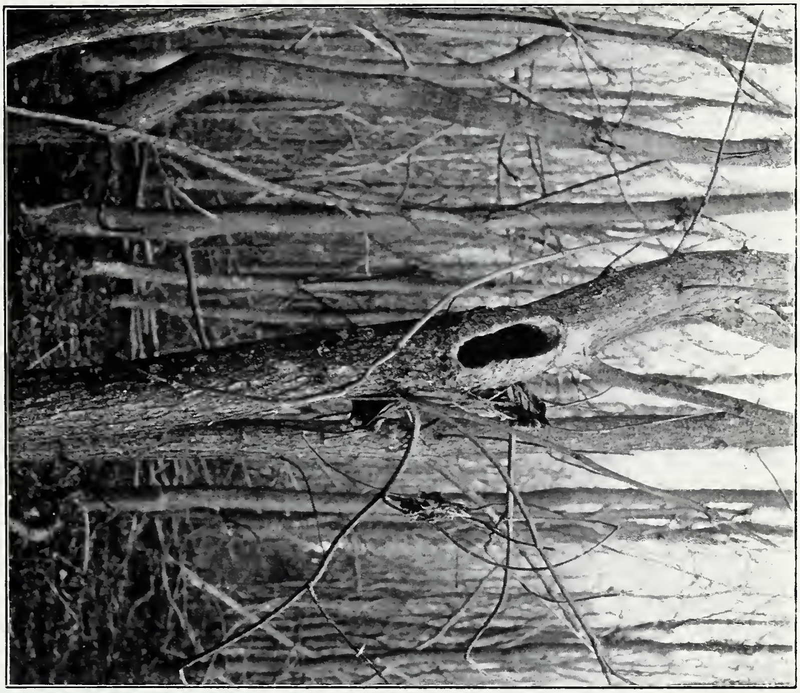

FIG. 1.—HOLE AND DECAYED HEART CAUSED BY A PERSISTENT DEAD LIMB, HUNNEWELL PLANTATION.

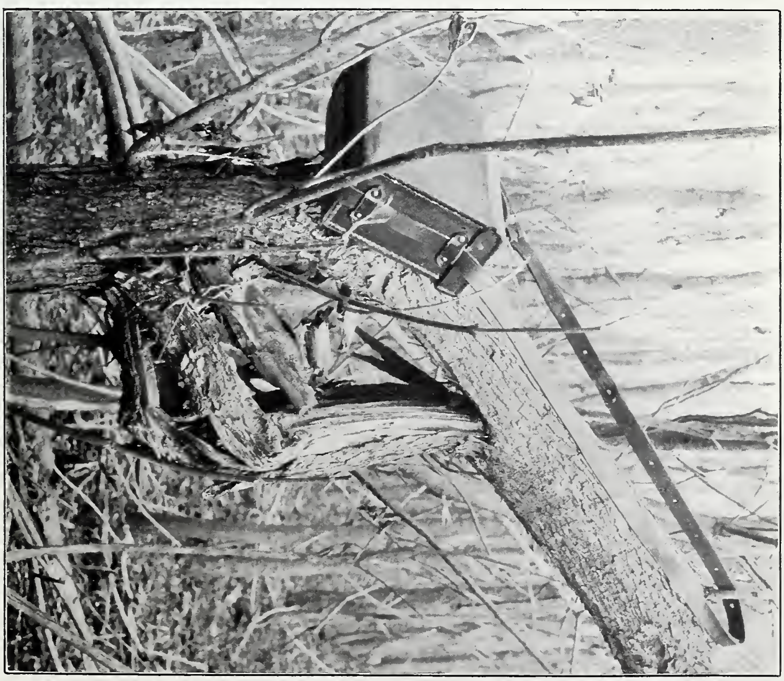

FIG. 2.—TREE BROKEN DOWN FROM DECAYED HEART CAUSED BY A PERSISTENT DEAD LIMB, HUNNEWELL PLANTATION.

trees and shrubs, such as Red Elm, White Elm, Red Mulberry, Wild Raspberry, Dogwood, and Poison Ivy. The value of the undergrowth is seen wherever it occurs. The soil moisture is retained better and the trees are more thrifty. The condition of thrift, however, is not due to this cause alone, but to the combined influence of soil, leaf cover, and undergrowth. The need of a uniform undergrowth in this plantation is most impressive. It has been needed since the trees were 12 years old. The parts of the plantation without it have no prospect of success. Those parts which have it depend largely upon its continuation to insure permanence of valuable growth.

LOSS DUE TO PERSISTENT BRANCHES.

The side branches of the Catalpa die in dense shade, but do not decay and drop off. Their presence as dead branches facilitates the entrance of the soft rot which consumes the heart of the tree, as described in Part II of this Bulletin. The evil consequences of such persistent dead branches are well illustrated in this forest. (See Pl. VI, fig. 1.) A count made of the diseased trees on a quarter acre in the best part of the plantation showed the following results:

Number of living trees	301
Sound	234
Decayed	67
Percentage decayed	22

The examination was made by removing the dead branches from the trees. By splitting the trunks some that are classed as sound would probably have been found decayed.

It is noticeable that the thrifty trees are most affected. In these the hole will sometimes be overgrown, leaving no exterior indication of decay until the tree is broken down by the wind. Many fine trees almost large enough for telegraph poles are ruined from this cause. (Pl. VI, fig. 2.) On a block of one-half acre (Block IX), trees of the following sizes were found broken on account of heart decay:

Diameter.	Broken trees.
2 to 3 inches	2
3 to 4 inches	17
4 to 5 inches	11
5 to 6 inches	7
6 to 7 inches	2
7 to 8 inches	4
8 to 9 inches	1
Total	44

These figures are too high for the entire plantation, but not for the best parts of it.

SOIL AND GROWTH CONDITIONS ON REPRESENTATIVE BLOCKS.

In order to describe and value the plantation, 10 blocks of one-half acre each (5 by 16 rods) were selected in different parts of the forest to represent the variation in growth. The blocks are numbered from I to X, Block I representing the poorest, Blocks V and VI the average, and Block X the best growth. The following notes describe the conditions on each block:

Block I.—The soil is a very poor loam, 6 to 8 inches deep, deficient both in humus and plant food. The subsoil is a very tenacious clay, difficult at all times for tree roots to penetrate, and extremely hard when dry. The trees are small and poorly shaped. Their growth has never been rapid. During severe drought the leaves fall from the trees, sometimes leaving them entirely bare in midsummer. The ground is covered by low-growing grass, which forms a dense sod that injures the trees. No woody undergrowth occurs. This block was planted in 1880 (see table of products), the same year as Block VIII, but the difference in growth is very striking.

Block II.—The soil is a poor loam, 10 to 12 inches in depth, and underlaid by clay. A scant supply of humus is found in the first 4 inches. The roots do not penetrate the subsoil well, apparently on account of the lack of available food. There is not enough leaf cover to prevent the growth of a low, densely sodding grass. A few specimens of Dogwood and Red Elm are scattered over the ground. At the time the study was made (August, 1900) the leaves had fallen from the trees on account of a drought of a month's duration.

Block III.—The soil of this block is a moderately fertile loam, 14 to 16 inches in depth. Humus extends to a depth of 6 or 8 inches. Below this the soil is of light ashy color. The subsoil is a loose, light-colored joint clay, becoming gravelly after a few inches. Tree roots penetrate both soil and subsoil fairly well with the result that the trees have made moderately good height growth. The ground cover is formed by leaves and twigs, and some shade-enduring weeds have appeared.

Block IV.—The soil in this block is similar to that in Block III. The subsoil differs by containing a large proportion of broken, soft, brown sandstone, which renders it porous and easily penetrated by the tree roots. The ground cover consists of twigs, leaves, and a scattered growth of shade-enduring weeds.

Block V.—The soil here is a rich, dark loam, 12 to 14 inches in depth, with the upper 6 or 8 inches well supplied with humus. A joint clay forms the subsoil, which, when moist, is easily penetrated by roots. The ground cover is composed of twigs, leaves, and a dense growth of weeds of the Borage family. This block represents the average growth of the plantation.

Block VI.—The soil and subsoil of this block are almost the same as in Block V. The ground cover also is the same with the exception of some Dogwood on this block.

Block VII.—The soil on this block is a rich, dark-colored loam, 12 to 16 inches in depth. It contains considerable humus near the surface. Lower down it is light in color. The subsoil is a light-colored joint clay of unknown depth. Both soil and subsoil are porous and easily penetrated by the tree roots. The result is visible in the rapid growth of the trees.

Block VIII.—The soil on this block is very similar to that on Block VII, but the subsoil differs slightly in containing a small percentage of loose gravel. The ground cover consists of leaves, twigs, and weeds. The most abundant weed is the White Snake Root (*Eupatorium ageratoides*) which makes a luxuriant growth. Here, as in other portions of the forest, there is but little leaf mold. The woody undergrowth consists of a few scattering bushes of Dogwood.

Block IX.—The soil on Block IX is a rich loam, colored dark for 8 or 10 inches below the surface by humus. Lower down the color is lighter. The subsoil is a porous, light-colored joint clay which freely admits the tree roots. The ground cover, which is quite abundant, is composed of leaves, twigs, and weeds. There is also some mold mixed with the surface soil, but this seems to have come principally from weeds and twigs rather than Catalpa leaves. This block is without woody undergrowth.

Block X.—The soil of this block is similar to that of Block IX, except that it is a few inches deeper, contains a little more humus, and has a more porous subsoil. The ground cover is composed of rather more than the usual quantity of debris, with a luxuriant growth of White Snake root, which attains a height of 3 to 4 feet and makes a dense shade. The woody undergrowth is not abundant, but some Red Elm is coming up. The trees are the oldest and among the finest in the plantation; a number of them being large enough for telegraph poles.

MEASUREMENTS.

On each block a count was made of the trees originally planted and those now living. Total height, length of bole, and diameter at 1 foot and 7 feet above ground were measured on each tree. The products of the tree were then estimated in posts, stakes, and telegraph poles. As will be seen in the tables which follow, the principal products were posts and stakes. A few trees only were suitable for telegraph poles.

In the accompanying tables the trees of the several blocks have been classified according to range of height and diameter.

NOTES ON HEIGHTS AND DIAMETERS.

The first table shows the height of the trees to range between 15 and 50 feet. Those in the poor parts of the plantation are lowest. as shown in Blocks I and II. In Block I all the trees are under 30 feet. On Block X, 32 out of the 44 per cent of living trees are over 30 feet. The number of dead or missing trees ranges from less than one-third in Block I to over one-half in Blocks IX and X. This shows that the struggle for existence has been more intense on the best soil, resulting in the death of a large proportion of the trees. while the remainder have made more vigorous growth. On the poor soil few trees have died, but none have made rapid growth. All have suffered about equally.

The second table shows the diameters of the trees to range between 2 and 12 inches. But 8 per cent of the trees on Block I and 4 per cent of those on Block II are over 5 inches in diameter, while in Block X about 25 per cent of the original stand, or more than half the living trees, are over 5 inches in diameter. Only 69 trees on the entire 5 acres were of the right size and form for telgraph poles.

Not a large number of telegraph poles can ever be obtained in this plantation. None of the trees on the poor soil will grow tall enough, and on the better soil a large percentage of the trees are forked or crooked. This difficulty can never be totally overcome in any plantation of Catalpa. The crookedness is due mainly to the dying of the tip of the leading branch in autumn without the formation of a terminal bud. This causes a lateral bud to form the leading shoot the following season. The buds are in whorls or pairs, and usually one side alternates with the other in forming the leader, thus often making the tree so crooked that it can never become straight. This is one of the most serious objections to the Hardy Catalpa as a timber for telegraph poles. (Pl. VII.)

Heights, Farlington forest.

One-half acre block.	Number of trees planted.	Dead or cut out.		Under 15 feet.		From 15 to 19 feet.		From 20 to 24 feet.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,386	447	32.2	48	3.5	240	17.3	388	28
II	1,386	466	33.6	114	8.2	606	43.7	174	12.6
III	1,320	476	36.1	22	1.5	129	9.8	274	20.8
IV	1,386	608	43.8	8	.6	48	3.5	145	10.5
V	1,386	721	52	....	....	47	3.4	169	12.2
VI	1,300	472	36.3	1	.1	24	1.8	100	7.7
VII	1,365	643	47.1	5	.4	45	3.3	191	14
VIII	1,386	623	45	5	.4	47	3.4	142	10.2
IX	1,365	831	60.9	9	.7	29	2.1	57	4.2
X	1,365	772	56.5	3	.2	21	1.5	49	3.7
Total	13,645	6,059	....	215	....	1,236	....	1,689	....
Average	1,364.5	605.9	41.35	21.5	1.56	123.6	8.98	168.9	12.39

Heights Farlington forest—Continued.

One-half acre block.	From 25 to 29 feet.		From 30 to 34 feet.		From 35 to 39 feet.		From 40 to 44 feet.		From 45 to 49 feet.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	263	19								
II	24	1.7	2	0.2						
III	241	18.3	148	11.2	30	2.3				
IV	361	26	147	10.6	69	5				
V	337	24.3	38	2.7	73	5.3	1	0.1		
VI	166	12.8	48	3.7	455	35	34	2.6		
VII	274	20.1	148	10.8	59	4.3				
VIII	247	17.8	157	11.3	165	11.9				
IX	80	5.8	133	9.8	137	10	69	5.1	20	1.4
X	80	5.9	90	6.6	154	11.3	163	11.9	33	2.4
Total	2,073		911		1,142		267		53	
Average	207.3	15.17	91.1	6.69	114.2	8.51	26.7	1.97	5.3	.38

Diameters, Farlington forest.

One-half acre block.	Number of trees planted.	Dead or cut out.		Under 2 inches.		From 2 to 2.9 inches.		From 3 to 3.9 inches.		From 4 to 4.9 inches.		From 5 to 5.9 inches.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,886	447	32.2	2	0.1	168	12.1	387	27.8	272	19.9	89	6.4
II	1,386	466	33.6	2	.1	172	12.4	443	32	246	17.7	53	3.9
III	1,320	476	36.1	22	1.7	125	9.5	262	19.8	228	17.3	132	10
IV	1,386	608	43.8	2	.2	108	7.8	223	16.1	217	15.6	134	9.7
V	1,386	721	52	2	.2	52	3.8	162	11.7	211	15.2	154	11.1
VI	1,300	472	36.3	2	.2	67	5.1	224	17.2	226	17.4	205	15.8
VII	1,365	643	47.1	2	.2	89	6.5	183	13.4	182	13.3	146	10.7
VIII	1,386	623	45			59	4.3	215	15.4	185	13.4	178	12.8
IX	1,365	831	60.9			20	1.5	58	4.2	128	9.4	127	9.3
X	1,365	772	56.5	2	.1	31	2.3	106	7.8	117	8.6	106	7.8
Total	13,645	6,059		36		891		2,263		2,012		1,324	
Average	1,364.5	605.9	44.35	3.6	.28	89.1	6.53	226.3	16.54	201.2	14.78	132.4	9.75

One-half acre block.	From 6 to 6.9 inches.		From 7 to 7.9 inches.		From 8 to 8.9 inches.		From 9 to 9.9 inches.		From 10 to 10.9 inches.		From 11 to 11.9 inches.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	18	1.3	1	0.1	2	0.1						
II	4	.3										
III	51	3.8	20	1.5	4	.3						
IV	66	4.8	19	1.4	9	.6						
V	60	4.3	20	1.4	4	.3						
VI	82	6.3	22	1.7								
VII	83	6.1	28	2.	8	.6	1	0.1				
VIII	82	5.9	37	2.7	7	.5						
IX	96	7.	65	4.8	29	2.1	6	.4	5	0.4		
X	105	7.7	67	4.9	41	3.1	14	1	2	.1	2	0.1
Total	647		279		104		21		7		2	
Average	64.7	4.75	27.9	2.05	10.4	.76	2.1	.15	.7	.05	.2	.01

RATE OF GROWTH.

Measurements on 50 trees, five medium-size samples on each block, show the rate of height growth in the plantation to have been as follows:

Age.	Height.
	Feet.
3 years	8
6 years	15½
9 years	21
12 years	26
15 years	29¾
18 years	33
21 years	34½

It has already been mentioned that a change took place in the plantation in the twelfth year in the thinning out of the foliage. That was not the only effect. The figures above show that the height growth, which between the sixth and ninth years had been 5 feet, fell to 3¾ feet between the twelfth and fifteenth years. In the table of volume increments which follows it is to be seen that there was a constant increase in the increment up to the twelfth year, but thereafter a sudden decline. On only one block (No. V) was the increment between the twelfth and fifteenth as great as between the ninth and tenth years. The average of the 50 trees shows by three-year periods how the increment increased rapidly till the ninth year, then more slowly till the twelfth year, after which there was a decided falling off. The table of diameter growth for the same trees shows the same results. Between the ninth and twelfth years the average diameter increased over 0.5 inch; between the twelfth and fifteenth years the increase was only 0.35 inch.

This shows that at the age of twelve the trees became too crowded for thrifty growth. The space being insufficient for all, the struggle for the possession of the soil became more intense until the weaker trees were overcome, while the stronger forged ahead and occupied the space which they had won. Mention has already been made that the struggle was fiercest on the better soil, where only 40 to 45 per cent of the trees survive. But these are the largest in the plantation.

Volume increment, Farlington forest.

[Average of 5 medium-size trees on each block.]

Block.	Average increment of successive periods of growth in cubic feet.						
	1 to 3 years.	4 to 6 years.	7 to 9 years.	10 to 12 years.	13 to 15 years.	16 to 18 years.	19 to 21 years.
I	0.0147	0.0616	0.1444	0.1739	0.1301	0.1476	0.1122
II	.0083	.0556	.1218	.1059	.1001	.1078	.1108
III	.0096	.0392	.1027	.1283	.1118	.1087	.1138
IV	.0240	.1436	.2809	.2351	.2103	.2112	....
V	.0107	.1434	.1694	.2064	.2110	.2485	....
VI	.0153	.1120	.2692	.3206	.1989	.2175	.1603
VII	.0285	.1658	.2914	.2962	.2757	.2466	....
VIII	.0681	.2691	.2862	.2533	.2155	.2246	....
IX	.0306	.1861	.3229	.3904	.3459	.3688	.2874
X	.0575	.2184	.3688	.3195	.3099	.3019	.3233
Total	.2673	1.3946	2.3577	2.4296	2.1092	2.1832	1.1328
Average	.02673	.13946	.23577	.24296	.21092	.21832	.1888

Diameter growth, Farlington forest.

[Average of 5 medium-size trees on each block.]

Block.	Growth in inches at successive periods.						
	Third year.	Sixth year.	Ninth year.	Twelfth year.	Fifteenth year.	Eighteenth year.	Twenty-first year.
I	1.12	1.81	2.46	3.11	3.32	3.59	3.79
II	.94	1.84	2.56	2.94	3.24	3.48	3.67
III	1.13	1.63	2.40	2.80	3.20	3.63	3.80
IV	1.35	2.39	3.19	3.54	3.91	4.12	....
V	1.10	2.34	2.90	3.44	3.89	4.18	....
VI	1.16	2.13	2.83	3.55	3.87	4.14	4.31
VII	1.30	2.43	3.34	3.66	4.05	4.35	....
VIII	1.94	3.07	3.65	3.98	4.24	4.45	....
IX	1.52	2.54	3.22	3.82	4.28	4.72	5.25
X	1.98	3.24	3.45	4.44	4.85	5.21	5.54
Average	1.354	2.342	3.00	3.528	3.885	4.187	4.39

RELATIVE AMOUNT OF HEARTWOOD, SAPWOOD, AND BARK.

The volume of the sample trees on each block and of the heartwood, sapwood, and bark is shown in the table which follows. The chief point of interest in the table is in the large proportion of heartwood. The 50 trees analyzed had an average of 73.18 per cent of heartwood, 10.96 per cent of sapwood, and 15.84 per cent of bark, which probably represents fairly well the average of Hardy Catalpa at this age. Heartwood begins to form when the tree is only two or three years

old. From this time on only from two to four of the outer annual rings remain as sapwood. The large proportion of heartwood makes the timber more valuable, whether considered for lumber or for use in the ground, than it would otherwise be. (Pl. VIII.)

Volume, Farlington forest.

[Five medium-size trees on each block.]

Block.	Heartwood.		Sapwood.		Heart-wood and sapwood.	Bark.		Whole tree.	
	Volume.	Per cent.	Volume.	Per cent.		Volume.	Per cent.	Volume.	Per cent.
	Cubic ft.		*Cubic ft.*		*Cubic ft.*	*Cubic ft.*		*Cubic ft.*	
I	0.7046	74.05	0.0799	8.40	0.7845	0.1670	17.55	0.9515	100
II	.5367	72.44	.0736	9.93	.6103	.1306	17.63	.7409	100
III	.6323	68.36	.1141	12.33	.7464	.1786	19.31	.9250	100
IV	.9922	72.33	.1669	12.17	1.1591	.2127	15.50	1.3718	100
V	.9225	74.27	.1665	13.40	1.0890	.1531	12.33	1.2421	100
VI	1.1453	74.87	.1485	9.71	1.2938	.2359	15.42	1.5297	100
VII	1.2207	77.20	.1384	8.75	1.3591	.2221	14.05	1.5812	100
VIII	1.1991	75.15	.1757	11.01	1.3748	.2208	13.84	1.5956	100
IX	1.7100	72.25	.2636	11.14	1.9736	.3931	16.61	2.3667	100
X	1.6795	70.88	.3024	12.76	1.9819	.3876	16.36	2.3695	100
Total	10.7429	....	1.6296	....	12.3725	2.3015	....	14.6740	100
Average	1.0743	73.18	.1630	10.96	1.2372	.2301	15.86	1.4674	100

PRODUCTS AND VALUE.

The products of the plantation are estimated in posts and telegraph poles. Two classes of posts are made. Those between 3 and 6 inches in diameter and 6½ feet long are valued at 8 cents each. Those between 2½ and 3 inches, 6½ feet long, are called stakes and valued at 4 cents each. The trees between 6 and 9 inches in diameter are reckoned as two posts per cut. A straight, unbranched tree, 9 inches or over in diameter at 1 foot above ground and 5 inches at 25 feet above ground, is classed as a telegraph pole and valued at $1.50. The following table shows the number of posts, stakes, and telegraph poles to be obtained on each of the half-acre blocks, and gives also the value of the products for each block:

TREES UNFIT FOR TELEGRAPH POLES ON ACCOUNT OF CROOKEDNESS AND FORKS, YAGGY PLANTATION.

SECTION SHOWING PROPORTION OF HEARTWOOD, SAPWOOD, AND BARK ON A 20-YEAR-OLD TREE OF HARDY CATALPA. (REDUCED FROM 9½ INCHES.)

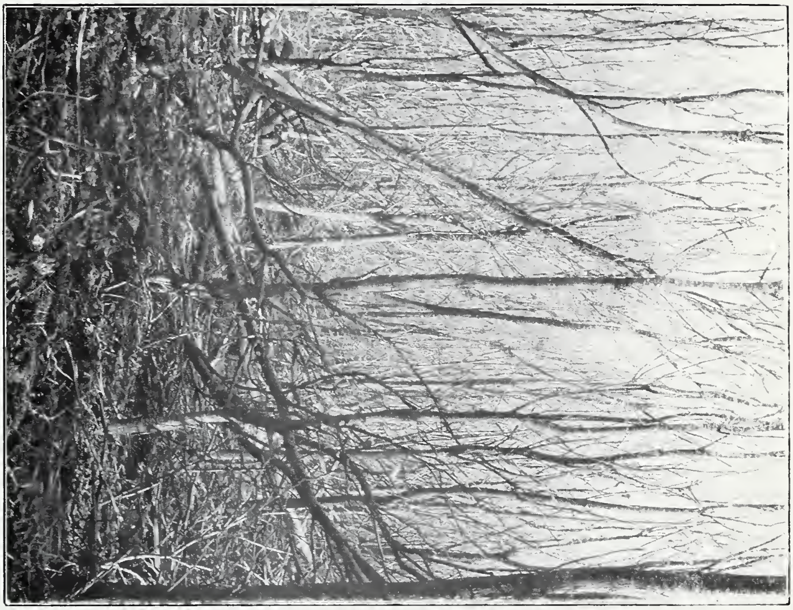

FIG. 1.—WASTEFUL CUTTING IN THE FARLINGTON FOREST.

FIG. 2.—CAREFUL CUTTING IN THE YAGGY PLANTATION. NO WASTE.

FIG. 1.—SOME OF THE BEST TREES IN THE HUNNEWELL PLANTATION.

FIG. 2.—TREE INJURED AT THE BASE BY A PERSISTENT DEAD LIMB, HUNNEWELL PLANTATION.

Products and value, Farlington forest.

Block.	When planted.	Posts.		Stakes.		Telegraph poles.		Total value.
		Number.	Value.	Number.	Value.	Number.	Value.	
I	1880	1,052	$84.16	812	$32.48			$116.64
II	1880	1,307	104.56	1,074	42.96			147.52
III	1881	1,632	130.56	933	37.32			167.88
IV	1877	1,625	130.00	1,031	41.24			171.24
V	1882	1,771	138.48	1,004	40.16			178.64
VI	1882	1,754	140.32	1,103	44.12			184.44
VII	1882	1,938	155.04	1,051	42.04	2	$3.00	200.08
VIII	1880	2,305	184.40	1,313	52.50			236.90
IX	1878	2,346	187.68	940	37.60	29	43.50	268.78
X	1877	2,346	187.28	867	34.68	38	57.00	278.96
Total for 5 acres		18,071	1,442.48	10,128	405.10	69	103.50	1,951.08
Average per acre		3,614	288.49	2,025	81.02			390.21

The average value per acre is seen from the table to be $390.21. This would give for the whole plantation of 400 acres a value of $156,084.

It is very interesting to give in this connection an estimate made on an entirely different basis. In the winter of 1900 the owners of the Farlington forest let a contract for the cutting of 125,000 posts. The specifications called for straight posts, 6½ feet long, measuring 4 inches in diameter at the top. These were sold at 10 cents each, or altogether $12,500. It was estimated that this cut removed one-tenth of the trees. Had all the timber been sold in that way the return would be $125,000. However, limiting the posts to a diameter of 4 inches at the top, without utilizing the smaller sizes, made the cut needlessly wasteful. Thousands of good, straight pieces only a little below the diameter limit were left on the ground to decay. They might easily have been removed and sold as second-class posts at from 5 to 8 cents each; and had this waste thus been prevented the returns from the cut would have been sufficiently increased to make the two estimates very nearly equal. (Pl. IX, fig. 1.)

In reckoning the cost per acre of the plantation there is included—

Cost of establishing, as per contract	$30.00
Rent of land, 21 years, at $2 per year	42.00
Cost of thinning, 1894	.62
Estimated cost of marketing products at 1 cent per post	36.14
Cost of superintendence, 21 years, at $0.75 per year	15.30
Total cost per acre	124.51

Subtracting from the gross value, $390.21, the cost, $124.51, there remains $265.70 as the net return on the investment. This is an average annual profit of $12.65 for the time the land has been occupied. Allowing 6 per cent interest compounded on the investment, the cost per acre of the plantation amounts, at the present time, to $252.02, and still leaves a clear profit of $138.19. At the net value, $265.70 per acre, the 400 acres of catalpa would have a clear value of $106,280.

The return on an acre in the poorest part of the plantation, as represented by Block I, is only $5.93 per annum, while the return from the best part, as represented by Block X, is $25.99 per annum. This shows beyond question the remarkable advantage of rich over poor soil for commercial timber growing. Probably in a farm crop the difference would not be half so great as it is here. This difference, however, shows what has often been doubted, that the greatest proportionate profit from the Hardy Catalpa in commercial plantations in the Middle West is to be had on the best agricultural land. It is on the very best soil that Catalpa will compete most successfully with corn and wheat as a money-making crop.

THE HUNNEWELL PLANTATION.

This body of timber is situated 5 miles southwest of Farlington and covers nearly 500 acres, with 400 acres of Hardy Catalpa and 100 acres of Ailanthus. The planting was begun in 1880 and finished in 1884. The whole plantation lies in a large southerly sloping flat which in conditions most nearly approaches upland. Several swales which run through the land assist in its drainage. The soil is a finely divided, ashy clay loam from 1 to 2 feet in depth and rather scantily supplied with humus. The subsoil over the entire plantation is a very stiff clay.

The trees were planted by Robert Douglas & Sons under a contract similar to that described for the Farlington forest, though at a less price per acre. The one-year-old seedlings used were mostly grown on the farm instead of being shipped from the nursery. The same cultivation was given as in the Farlington forest. By the end of the third season the trees were all out of the contractor's care and received no further cultivation except in a few places where the ground was particularly hard. Each 40-acre tract is surrounded by an unplanted strip 20 feet wide, which has been kept plowed as a fire guard. Several of these strips are used as roads and form a beautiful system of drives. Further than the plowing of these strips the plantation had no special attention till February, 1895, when a large number of the trees were removed. The poorest tree in every four was taken out.

unless one or more of the four were dead. This work required four men six weeks and cost $236, or 59 cents per acre. Since 1895 no work has been done except to keep the fire guards plowed.

CONDITIONS.

In many ways the condition of this plantation is intermediate between the Munger plantation and the Farlington forest. In both age and development it is between them. Certain other conditions which are not yet apparent in the Munger plantation but are quite fully developed in the Farlington forest are just becoming noticeable here. Within the last three or four years the leaf canopy has become noticeably thinner. The ill effect of persistent branches is becoming pronounced through the decay and breaking down of trees, and the absence of undergrowth is just beginning to show its evil consequences. The amount of natural undergrowth in this plantation is less than in either of the others; consequently the need of some kind of planted undergrowth is more pronounced than in the other plantations. In a few places on the very best soil there is a dense growth of White Snakeroot (*Eupatorium ageratoides*), which serves admirably the purpose of ground cover. The leaf cover in this as in the other plantations varies from several inches in thickness on the best soil to nothing on the poor soil.

The leaf canopy is not now dense enough to fully exclude the sunlight. Looking upward one may see that the tops of the trees do not nearly fill the space. The reason of this is that the tops of the trees, thrashed back and forth by the wind, lose the foliage on their exposed edges.

MEASUREMENTS.

In order to estimate the quantity and value of the timber in the plantation a series of 10 half-acre blocks was laid off, corresponding exactly to the series used in measuring the Farlington forest. Block I represents the growth on poor soil, where the humus is scanty and the clay subsoil lies close to the surface. From this, succeeding blocks represent a better condition of soil, and consequently of tree growth, to the last, Block X, which represents the best conditions in the plantation. Here the soil is an extremely rich black marl, 2 to 2½ feet deep, with abundant humus throughout. Its moisture capacity is large, and, covered as the ground is with a heavy leaf mulch, and protected by a dense undergrowth, there is nearly always abundant moisture in the soil, regardless of the heavy demands of the trees. (Pl. V, fig. 2, and Pl. X, fig. 1.)

On each of the blocks the trees were calipered at 1 and at 7 feet above ground, the length of bole and the total height were taken, and the usual estimates made on the products of the trees in posts, stakes, and telegraph poles. The following tables show the heights and diameters of the trees in the ten blocks:

Heights, Hunnewell plantation.

One-half acre block.	Number of trees planted.	Dead or cut out.		Under 15 feet.		From 15 to 19 feet.		From 20 to 24 feet.		From 25 to 29 feet.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,365	651	47.7	57	4.2	268	19.6	308	22.6	81	5.9
II	1,365	426	31.2	36	2.6	249	18.3	493	36.1	161	11.8
III	1,344	638	47.5	21	1.6	77	5.7	327	24.3	268	19.9
IV	1,365	405	29.7	16	1.2	93	6.8	84	6.1	177	13
V	1,386	595	42.9	8	.6	76	5.5	117	8.4	223	16.1
VI	1,365	577	42.3	23	1.6	111	8.1	105	7.7	188	13.7
VII	1,320	602	45.6	36	2.7	80	6.1	39	2.9	393	29.8
VIII	1,386	705	50.9	30	2.2	95	6.8	59	4.3	77	5.5
IX	1,386	571	41.3	28	2	92	6.6	123	8.8	131	9.4
X	1,365	777	56.9	3	.2	5	0.4	41	3	53	3.9
Total	13,647	5,947	......	258	......	1,146	......	1,696	....	1,752	....
Average	1,364.7	594.7	43.6	25.8	1.89	114.6	8.39	169.6	12.42	175.2	12.9

One-half acre block.	From 30 to 34 feet.		From 35 to 39 feet.		From 40 to 44 feet.		From 45 to 49 feet.		From 50 to 54 feet.		From 55 to 59 feet.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	......	......	......	......	......	......	......	......	......	......	......	......
II	......	......	......	......	......	......	......	......	......	......	......	......
III	9	0.7	4	0.3	......	......	......	......	......	......	......	......
IV	228	16.7	336	24.6	26	1.9	......	......	......	......	......	......
V	228	16.5	137	9.9	2	.1	......	......	......	......	......	......
VI	149	11.0	208	15.3	4	.3	......	......	......	......	......	......
VII	137	10.4	33	2.5	......	......	......	......	......	......	......	......
VIII	90	6.5	163	11.8	121	8.7	46	3.3	1	0.1	......	......
IX	180	13	257	18.6	3	.2	......	......	......	......	......	......
X	58	4.3	72	5.3	149	10.9	109	7.9	96	7	2	0.2
Total	1,079	......	1,210	......	305	......	155	......	97	......	2	......
Average	107.9	7.9	121	8.83	30.5	2.21	15.5	1.12	9.7	.71	.2	.02

Diameters, Hunnewell plantation.

One-half acre block.	Number of trees planted.	Dead or cut out.		Under 2 inches.		From 2 to 2.9 inches.		From 3 to 3.9 inches.	
		Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	1,365	651	47.7	18	1.4	136	10	206	15.1
II	1,365	426	31.2	10	.7	194	14.2	360	26.4
III	1,344	638	47.5	7	.5	121	9	278	20.7
IV	1,365	405	29.7	4	.3	167	12.2	346	25.3
V	1,386	595	42.9	8	.6	100	7.2	275	19.8
VI	1,365	577	42.3	5	.4	94	6.9	264	19.3
VII	1,320	602	45.6	3	.2	109	8.2	237	18
VIII	1,386	705	50.9	4	.3	97	7	155	11.2
IX	1,386	571	41.3	14	1	167	12	244	17.6
X	1,365	777	56.9	....	....	25	1.8	118	8.7
Total	13,647	5,947	....	73	....	1,210	....	2,483	....
Average	1,364.7	594.7	43.6	7.3	.54	121	8.85	248.3	18.21

One-half acre block.	From 4 to 4.9 inches.		From 5 to 5.9 inches.		From 6 to 6.9 inches.		From 7 to 7.9 inches.		From 8 to 8.9 inches.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
I	221	16	105	7.7	23	1.7	4	0.3	1	0.1
II	230	16.9	99	7.3	22	1.6	10	.7	14	1
III	219	16.3	68	5.1	11	.8	2	.1	....	....
IV	247	18.1	146	10.7	39	2.9	11	.8	....	....
V	229	16.5	133	9.6	34	2.5	9	.7	3	.2
VI	212	15.5	129	9.4	65	4.7	13	1	5	.4
VII	206	15.6	118	9	36	2.7	9	.7	....	....
VIII	165	11.9	124	8.9	98	7	33	2.4	5	.4
IX	217	15.6	109	7.8	44	3.2	15	1.1	3	.2
X	117	8.6	107	7.8	82	6	73	5.4	39	2.9
Total	2,063	....	1,138	....	454	....	179	....	70	....
Average	206.3	15.1	113.8	8.33	45.4	3.31	17.9	1.32	7	.52

One-half acre block.	From 9 to 9.9 inches.		From 10 to 10.9 inches.		From 11 to 11.9 inches.		From 12 to 12.9 inches.		From 13 to 13.9 inches.	
	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.	Number.	Per cent.
VI	1	0.1	....	....	....	....	....	....	....	....
VII	....	....	....	....	....	....	....	....	....	....
VIII	....	....	....	....	....	....	....	....	....	....
IX	1	.1	....	....	....	....	1	0.1	....	....
X	17	1.2	7	0.5	2	0.1	....	....	1	0.1
Total	19	....	7	....	2	....	1	....	1	....
Average	1.9	.14	.7	.05	.2	.01	.1	.01	.1	.01

The first table shows a height variation of from 15 to over 55 feet. On Blocks I and II all the trees are below 30 feet; on Block X nearly all are above that height. In connection with the number which are dead or out, it should be borne in mind that the thinning in 1895 removed probably one-fourth of the original trees.

The second table shows that the diameters range between 2 and 10 inches, with scattering trees in the best growth running up to 12 and even 14 inches. The largest class is composed of those having diameters between 3 and 4 inches. There is almost exactly the same proportion of living trees as in the Farlington forest. In the manner and rate of growth, however, the two plantations have differed considerably, as will be seen under the heading which follows.

RATE OF GROWTH.

The average height growth in this plantation by three-year periods, as shown by the analysis of five sample trees on each of the 10 blocks, has been as follows:

Age.	Height.
	Feet.
3 years	10
6 years	16½
9 years	22
12 years	25½
15 years	27
18 years	29½

This shows a more rapid growth for the first nine years and a slower growth for the second nine years than the Farlington forest. The first difference probably accounts for the second. Vigorous growth at first caused the trees to become crowded by their ninth year. Growth received a sudden check at that time and since has never regained its former rate. There seems to be no other cause for the retarded growth than crowding and the attendant thinning out of the foliage.

The tables of volume and diameter increment show the same condition. In volume increment the Hunnewell plantation exceeded the Farlington forest till the sixth year, but thenceforth fell greatly behind it. In the period between the ninth and twelfth years its volume increment was nearly 25 per cent less. At the end of the eighteenth year the volume of the average tree in the Hunnewell plantation was 0.9407 cubic foot, and in the Farlington forest 1.0742 cubic feet—14 per cent greater. In diameter growth also the former exceeded the latter for the first nine years, but after that time fell considerably behind it.

The tables emphasize the fact that the rapid early growth of the trees resulted by the ninth year in a very crowded condition in the plantation and a material decrease in growth. Probably even the thinning four years later accomplished little more than the removal of the sup-

pressed trees, which could have no effect whatever on the thrift of the plantation, for the removal of a dying tree has no effect on a crowded stand.

Volume increment, Hunnewell plantation.

[Average of 5 medium-size trees on each block.]

Block.	Volume increments by 3-year periods to 18 years, in cubic feet.						
	From 1 to 3 years.	From 4 to 6 years.	From 7 to 9 years.	From 10 to 12 years.	From 13 to 15 years.	From 16 to 18 years.	From 19 to 21 years.
I	0.0089	0.0471	0.0862	0.1507	0.1961	0.1424	....
II	.0145	.1082	.1592	.1416	.1350	.1721	....
III	.0243	.1118	.1199	.1405	.1688	.1219	....
IV	.0460	.1499	.1948	.1863	.1767	.2189	....
V	.0222	.1187	.1930	.1966	.1422	.1554	0.1309
VI	.0317	.1576	.1788	.1785	.1848	.1220	....
VII	.0413	.2082	.2589	.1781	.1501	.1504	....
VIII	.0426	.1616	.2135	.1556	.2649	.2390	....
IX	.0594	.1092	.1889	.1709	.1596	.2759	....
X	.0772	.3035	.4086	.3864	.2382	.2624	....
Total	.3681	1.4758	2.0018	1.8852	1.8164	1.8604	.1309
Average	.0368	.1476	.2002	.1885	.1816	.1860	.1309

Diameter growth, Hunnewell plantation.

[Average of 5 medium-size trees on each block.]

Block.	Growth in inches at successive periods.						
	Third year.	Sixth year.	Ninth year.	Twelfth year.	Fifteenth year.	Eighteenth year.	Twenty-first year.
I	1.1	1.75	2.46	3.01	3.47	3.68	....
II	1.3	2.30	2.93	3.26	3.32	3.78	....
III	1.4	2.30	2.84	3.14	3.44	3.60	....
IV	1.66	2.43	2.91	3.24	3.53	3.76	....
V	1.23	2.20	2.76	3.22	3.46	3.64	3.855
VI	1.45	2.53	3.10	3.43	3.74	3.93	....
VII	1.68	2.70	3.34	3.64	3.85	4.07	....
VIII	1.69	2.60	3.21	3.57	3.91	4.18	....
IX	1.36	2.33	2.86	3.26	3.61	3.91	....
X	1.97	3.05	3.64	4.20	4.37	4.63	....
Total	14.84	24.19	30.05	33.97	36.70	39.18	3.855
Average	1.484	2.419	3.005	3.397	3.67	3.918	3.855

RELATIVE AMOUNT OF HEARTWOOD, SAPWOOD, AND BARK.

The tables of height, volume increment, and diameter growth showed on the whole a less rapid rate of growth in this plantation than in the Farlington forest. This difference is further emphasized by the table under this heading, which shows the total volume of the bole and the amount of sapwood and heartwood. A comparison of tables for the two plantations will show the Farlington forest to be much ahead, both in total volume and amount and percentage of heartwood.

Volume, Hunnewell plantation.

[Five medium-size trees on each block.]

Block.	Heartwood.		Sapwood.		Bark.		Whole tree.	
	Volume.	Per cent.	Volume.	Per cent.	Volume.	Per cent.	Volume.	Per cent.
	Cubic ft.		*Cubic ft.*		*Cubic ft.*		*Cubic ft.*	
I	0.5354	73.64	0.0963	13.24	0.0954	13.12	0.7268	100.00
II	.6235	66.27	.1496	15.90	.1678	17.83	.9408	100.00
III	.5894	73.32	.0979	12.19	.1164	14.49	.8036	100.00
IV	.8566	70.21	.1814	14.86	.1820	14.92	1.0200	100.00
V	.8278	73.16	.1312	11.58	.1730	15.27	1.1319	100.00
VI	.7367	73.03	.1332	13.20	.1389	13.77	1.0088	100.00
VII	.8454	74.61	.1417	12.50	.1461	12.89	1.1331	100.00
VIII	.9085	71.80	.2022	15.98	.1547	12.22	1.2653	100.00
IX	.7934	62.73	.2768	21.86	.1947	15.41	1.2649	100.00
X	1.5063	75.66	.2209	11.13	.2631	13.21	1.9903	100.00
Total	8.2230		1.6312		1.6321		11.2855	
Average	.8223	71.44	.1631	14.24	.1632	14.32	1.1285	100.00

PRODUCTS AND VALUE.

The same valuation is placed upon the products as in the Farlington forest; viz. posts, 3 to 6 inches in diameter, 6½ feet long, 8 cents each; stakes, 2½ to 3 inches in diameter, 6½ feet leng, 4 cents each; telegraph poles, 9 inches at butt, 5 inches at top, 25 feet long, $1.50. No valuation is places upon the waste products which might be used as firewood. The following table shows the products and value of each block:

Products and value, Hunnewell plantation.

Block.	Posts.		Stakes.		Telegraph poles.		Total value of trees.
	Number.	Value.	Number.	Value.	Number.	Value.	
I	1,029	$82.32	530	$21.20			$103.52
II	1,264	101.12	1,028	41.12			142.24
III	1,499	119.92	995	39.80			159.72
IV	1,642	131.36	1,081	43.24	2	$3.00	177.60
V	1,852	148.16	1,062	42.48			190.64
VI	1,843	147.44	1,169	46.76	2	3.00	197.20
VII	1,879	150.32	1,199	47.96			198.28
VIII	1,934	154.72	1,083	43.32	2	3.00	201.04
IX	2,037	162.96	1,371	54.84			217.80
X	2,527	202.16	1,008	40.32	34	51.00	293.48
Total	17,506	1,400.48	10,526	421.04	40	60.00	1,881.52
Average per acre	3,501	280.09	2,105	84.21	8	12.00	376.30

The value of the products varies from $103.52 on Block I to $293.48 on Block X. The acreage average as found by dividing the sum of the values of the 10 blocks by 5 is $376.30, making the present value of the entire plantation of 400 acres $150,520.

INTERIOR VIEW OF THE YAGGY PLANTATION.

ROW CUT OUT IN YAGGY PLANTATION TO FACILITATE THE REMOVAL OF POSTS.

FIG. 1.—POSTS FROM THE FARLINGTON FOREST.

FIG. 2.—POSTS FROM THE PLANTING OF 1890, YAGGY PLANTATION.

THE GROWTH OF HARDY CATALPA ROOTS IN SANDY LOAM, YAGGY PLANTATION.

The expenses of establishing and maintaining the plantation, reckoned per acre, are as follows:

Cost of planting and cultivating as per contract	$25.00
Rent of land, 18 years, at $2 per acre	36.00
Cost of thinning in 1895	.59
Cost of marketing products (estimated)	35.01
Cost of superintendence, 18 years at $0.75 per year	13.60
Total	110.20

Subtracting from the acreage value ($376.30) the acreage cost ($110.20), there is left $266.10, the net return on the investment. Averaged for the eighteen years the plantation has occupied the land, there is a net return of $14.78 for each year.

The difference in value of the different blocks is worthy of note. The acreage value of the poor land, as represented by Block I, is only $207.04. After expenses are subtracted this gives an annual return of only $5.37. The acreage value of the best land, as represented by Block X, is $586.96. After the expense is subtracted from this there is a net annual profit of $26.47. Thus the actual profit on the good land is about five times as great as on the poor land.

If compound interest is computed on the investment at 6 per cent, the expense of the plantation per acre amounts to $199.43, leaving still a clear profit of $176.87.

THE YAGGY PLANTATION.[a]

The well-known plantation of L. W. Yaggy is located 4 miles northwest of Hutchinson, Reno County, Kans., in the rich valley of the Arkansas River. It is younger than any of the foregoing plantations, but on account of the intensive methods used in its management it is most interesting. Planting was begun in 1890 and completed in 1892. One hundred and sixteen acres were planted the first, 80 acres the second, and 225 acres the third year. (Pl. XI.)

Except on 80 acres, where the planting is 3 feet 10 inches by 7 feet, the trees stand uniformly 3 feet 10 inches east and west by 6 feet north and south. At this distance there were 1,894 trees per acre. On account of the difficulty and expense of obtaining trees from a nursery for planting so large a tract, seedlings were grown on the farm. When one year old the trees were set in furrows in which was stretched a line marked at proper intervals for planting. A fair alignment was thus secured in all directions. The trees grew vigorously from the start and could be cultivated but two years.

The southwest corner of the section of land containing the plantation is cut off by the Arkansas River. Near the river the soil is very

[a] A preliminary report on this plantation is to be found in Bulletin No. 27 of the Division of Forestry.

sandy, but farther away it changes into a sandy loam several feet in thickness and underlaid in most places by a soft, bluish clay, which also contains a large amount of sand. Both soil and subsoil are easily permeable to moisture and tree roots, and, except where very sandy, are well adapted to forest growth. The water table is found from 4 to 10 feet below the surface. Subirrigation is, therefore, almost perfect.

As the trees were planted at different times and have received somewhat different treatment, the tract is divided into compartments according to the order of planting.

THE PLANTING OF 1890.

In the spring of 1890 the south half of the northeast quarter and 36 acres of the northeast quarter of the southeast quarter, altogether 116 acres, were planted.

THE SOUTH HALF OF THE NORTHEAST QUARTER.

The trees were allowed to stand two years and were then cut back to the ground. Six years later, in the winter of 1897 and 1898, about 15,500, or approximately one-eighth, of the best trees were cut. Each tree averaged two posts. The next work was in the winter of 1901 and 1902, when enough trees were cut to remove about half the original stand. About 120,000 posts were obtained. The previous cut brings the number up to 151,000. Almost half the trees remain, and the stand is now 6 by 6⅔ feet.

Every alternate north and south row has been removed. Besides, each twentieth row east and west was cut to afford roadways to collect the posts and poles. (Pl. XII.)

The cutting was done by contract. The choppers felled the trees, cleared them of side branches, and carried them to the roadways. This cost on the average one-half cent per tree. It cost an equal amount to haul the poles to the saw outside the plantation. A circular saw, run by a 4-horsepower engine, was used to cut the poles into posts and firewood. Careful cutting and sawing prevented the loss of any considerable part of the poles. Some of the trees furnished posts 8, 10, and even 12 feet long. There is a ready sale for such lengths in that region, for use in the construction of farm outbuildings, and they brought the handsome price of 25, 35, and 50 cents, respectively. (Pl. XIII, fig. 2.)

This tract lies about half a mile from the river, and has very rich soil. It contains some of the straightest and tallest trees of the entire plantation.

MEASUREMENTS.

Three blocks of one-half acre each (5 by 16 rods), selected to show average growth on the tract, were taken for measurement. The same measurements were made as described in connection with the foregoing plantations, and the number of first, second, and third class posts in each tree estimated. As eleven-twentieths of the trees had been cut previously, the number of trees and the products should be proportionately increased to give the true value.

Block I contains some inferior growth. The soil is a very sandy loam, 3 feet deep, underlaid by 1 foot of pure sand, but covered and mixed to a depth of 4 inches with humus. Beneath the layer of sand is 5 inches of light clay, and below this again, sand. The loam is well filled with roots, which, however, do not extend into the sand.

Block II is in one of the best parts of the whole plantation. The soil differs from that in Block I by the loam being deeper, crowding out entirely the layer of sand over the clay. Below the clay, as on Block I, there is pure sand. Here, again, roots penetrate the loam but not the sand. (Pl. XIV.)

Block III represents the best growth on the tract, as well as on the whole plantation. The soil on this block, too, is about 3½ feet deep, and underlaid by pure sand. Nevertheless an interesting contrast is presented to Block I, where the soil is of equal depth and penetrated to equal extent by tree roots. Apparently the sole difference is in fertility. The soil on this block is richer than on the other, hence the better growth.

THE NORTHEAST QUARTER OF THE SOUTHEAST QUARTER.

This tract contains the rest of the planting of 1890. The trees had the same treatment in planting as the other trees planted the same year. They were cut back to the ground in January, 1892. Thereafter no treatment was given until five years ago. Since then a few trees have been promiscuously cut for posts, and in the winter of 1899 and 1900 about one-third of the trees were removed by the selection system, the smaller trees being selected for removal to give room for the better development of the larger ones. It is the intention to keep down the sprouts from the stump and even kill the stumps if possible. Thus far the sprouts have been kept down by cutting, but a tinner's furnace lamp is to be tried for burning them. The side branches have also been removed from the remaining trees.[a] They are now excellent young poles and will be left to produce large timber. The splendid growth of this part of the plantation seems due entirely to the soil, which is fertile and deep and has a good supply of humus and abundant leaf cover. (Pl. XV.)

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[a]The pruning was done without cost by men who wanted the branches for fuel.

Blocks IV and V were taken in this tract. A soil examination on Block IV showed 2½ feet of sandy loam thickly penetrated by tree roots, 14 inches of rather heavy clay, and 20 inches of heavy clay containing calcareous nodules. Fibrous roots extend well into and some even through the first layer of clay. In the cutting two years ago 399 trees were removed from this block. On Block V 368 trees have been cut within the last five years. The best soil conditions in the entire plantation are found on this block. A good cover of leaves overlies the surface. The soil, a light sandy loam, well supplied with humus, is 3 feet deep. Below the loam is 15 inches of sandy clay underlaid by 6 inches of gumbo. Beneath the latter are 2 feet of clay filled with calcareous gravel. The tree roots extend through the loam and well into the clay.

THE PLANTING OF 1891.

THE SOUTH HALF OF THE NORTHWEST QUARTER.

This compartment of 80 acres contains the only planting done in 1891. The record does not show these trees to have been cut back, but analysis of the trees in March, 1902, showed but ten years' growth. So the trees must either have been cut back when 1 year old or else have been planted in the fall of 1891. In either case the growth of that year would not appear on the basal section. The soil over the entire tract is well adapted to the Catalpa; nevertheless the trees, without exception, show a low, much-branched form. Dead side branches still cling to the trees from the ground up. This is almost proof positive that the trees have never been cut back and that they were planted in the fall. A comparison of the trees on this 80 acres with those which are known to have been cut back show a marked contrast and an overwhelming advantage for the trees which were cut back. (Pl. XVI.)

The trees on this tract can never attain great value. Good posts can be secured from the base but not from the upper cuts.

The owner expects to cut all the trees on this tract next winter and restock by training up the sprout growth. This method is certainly to be advised. Superior growth can be secured from the sprouts by clear cutting. The present stand can be marketed and the brush cleared from the ground at a cost much less than would be entailed by gradual thinning or strip cutting. The special advantage of renewing the stand by sprouts is the securing of straight, tall, branchless trunks with uniform taper, such as will cut posts 8, 10, and 12 feet in length. (See Pl. XVII.) Posts of these lengths, as already mentioned, are worth from two to four times as much as the 6½-foot lengths.

There is a good leaf cover over all this tract. The shade being very dense, undergrowth of all kinds is excluded.

MEASUREMENTS

Blocks VI, VII, and VIII (one-half acre each) were taken on this tract. Block VI is located near the west end, where the surface soil consists of 2 feet of sandy loam, and is well supplied with humus. The subsoil is pure, fine, yellow sand, separated from the soil by a 4-inch stratum of light clay. The water table is 5½ feet below the surface. Roots extend throughout the loam and into the clay. A very few penetrate the sand for a few inches. They probably do not go deeper on account of the too abundant moisture.

Block VII is near the northeast corner of the tract. It resembles Block VI in all particulars, but the soil is somewhat deeper, the layer of clay slightly thicker, and the water table a little lower. Altogether the soil conditions are better.

The conditions on Block VIII are different. Here the top soil is a very sandy loam 3 feet deep underlaid by pure sand. The clay is wanting, and the water level is 6½ feet below the surface. The soil is deeper than on the other blocks and the underground water is nearer the surface, yet the trees are much poorer. They are not over 12 feet high. Their poor growth is undoubtedly due to the soil, which is too coarse and sandy to be rich, and to the want of a clay subsoil. As it is, the elements of fertility are constantly leached from the soil and lost. The clay on the other blocks is of immense advantage.

THE PLANTING OF 1892.

The planting of 1892 consisted of the north half of the northwest quarter, the south half of the southeast quarter, and about 55 acres on the south half of the southwest quarter.

THE NORTH HALF OF THE NORTHWEST QUARTER.

The tract of 80 acres, which was planted 3 feet 10 inches by 7 feet, was well cultivated for the first two years following planting, but for the three thereafter had no special attention. At the end of that time (autumn, 1896) it was thought that the growth might be improved by cutting down the stand entirely and allowing the trees to reproduce by sprouts. This was done in the following manner: Strips 10 rows wide were cut through the tract east and west, leaving three rows between each strip for wind-breaks. The trees had scarcely any value for posts, but the wood was worth enough to pay for the cutting. Vigorous sprouts sprang up from the stumps. After thinning these out to a single sprout for each stump no further work was done until the fall of 1901, when the trees were pruned of sprouts and side branches as high as 7 feet. This cost $1.25 per half-mile row, or $268.75 for the 80 acres. The rows which were left for wind-breaks were cut, part in the fall of 1899, part in the fall of 1900.

The trees on this tract are rapidly becoming valuable. All have straight, long trunks, with a uniform taper. There are now many first-class posts, and within a year or two almost every tree will furnish a good post from the bottom cut. The trees are now almost as high as the 10-year-old trees growing on the south which were not cut back.

Heavy foliage has resulted from the cutting back in 1896. The ground is well covered by leaves, and the shade has been so dense as to keep down all undergrowth.

The soil of this tract is very good, and the trees are going to produce marketable posts within six years from the time of cutting back. It is probable that this tract will produce as large future returns as any other part of the plantation.

MEASUREMENTS.

Three blocks, Nos. IX, X, and XI, were taken on this tract. Block IX is near the northwest corner. Its soil is sandy loam 1 foot deep, underlaid by 1½ feet of fine sand. At the bottom this shades into coarse sand and gravel, which continues to water level, 5½ feet below the surface. Tree growth is excellent. Though the surface soil is not deep it is fertile, and the trees receive an abundance of water from below. The roots extend through the loam and penetrate the sand to some extent, but none go clear to the water table.

Block X is on the east side of the tract. Tree growth here is also good, though the soil is very different. A moderately sandy loam furnishes the surface soil for 20 or 22 inches. Beneath is 14 inches of light clay, containing an abundance of calcareous nodules. Below the clay is pure sand.

Block XI is on the south side where the growth is poor and the trees small. Measurement showed 4 feet of very sandy loam and 4 feet of sand before the water table was reached. Roots reach the sand but do not penetrate it. The mean growth is unquestionably due to poverty of the soil.

THE SOUTH HALF OF THE SOUTHEAST QUARTER.

The greater part of this tract lies in the river bottom and has been overflowed at times, though not within the last few years. Some 25 acres on the north side are on what is called the second bottom, and lie about 6 feet higher than the rest. On this second bottom the soil is both deep and fertile. Consequently the trees are thrifty. They compare favorably with those in Blocks IV and V. The trees on the lower parts of the tract are very inferior, because the soil is extremely sandy and poor.

The entire tract, except strips 3 rows wide left for wind-breaks after every twentieth row, was cut in January and February, 1901. The north side, already described, furnished good posts and gave very good returns, but the trees cut on the low sandy gound did not much more than pay the expense of cutting. The owner thinks that by pruning up the sprout growth on this land good post timber can be secured, but longer time will be required than on better land. The stump sprouts were kept cut back to one for each tree during last summer. (Pl. XVIII).

MEASUREMENTS.

Block XII in the following tables was taken in this tract and consists of one row east and west (0.4 acre) in one of the shelter belts, through the lower part of the plantation. It is an average of about 55 of the 80 acres. Where the tree growth is poorest there is a surface soil of 10 inches consisting of alluvial loam. Below the loam is pure sand. The water level is 3½ feet below the surface. Where the growth is better the soil is found to be deeper and the water level lower.

THE SOUTH HALF OF THE SOUTHWEST QUARTER.

The tract resembles closely the one last described. About 20 acres on the north side are on second bottom land, and there the trees have grown well. As one approaches the river the soil becomes correspondingly poor. At the southwest corner the river cuts out about 15 acres. On the 40 acres next to the river the trees are practically worthless, as the soil is too poor for them to grow.

The entire tract was cut off one and two years ago except a few rows on the north side left as a windbreak on the south of an orchard. The 20 acres on the north side made good posts, but the rest was practically worthless. On the very poorest ground the sprouts made a growth of 2 to 6 feet the first year, but only 1 or 2 feet the second. As the trees had all been cut off no measurement could be made.

HEIGHTS AND DIAMETERS.

The purpose of the tables under these headings is to show the range in height and diameter of the trees in various parts of the plantation. It will be seen in the table of heights that few of the trees are under 15 feet, and almost none over 25 feet. The exceptions are in Blocks IX, X, and XI, where the trees have had but five years' growth since they were cut back, and Block XII, which is on extremely poor soil.

The table of diameters shows most of the trees to measure between 2 and 5 inches at 1 foot above ground. Some on every block except No. XI are over 5, but only a few are above 6 inches.

Heights, Yaggy plantation.

Block.	Under 15 feet.		From 15 to 19 feet.		From 20 to 24 feet.	
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.
I	36	8.85	191	46.93	150	36.85
II	5	1.24	82	20.35	154	38.21
III	37	8.89	89	21.39	275	66.11
IV	1	.20	112	22.90	318	65.02
V	4	.75	74	13.86	442	82.77
VI	38	4.23	499	55.57	361	40.20
VII	40	5.02	454	56.96	294	36.89
VIII	5	.65	297	38.57	466	60.52
IX	75	11.61	356	55.11	214	33.13
X	86	12.54	465	67.78	135	19.68
XI	88	12.12	605	83.33	33	4.55
XII	500	84.89	79	13.41	10	1.70
Average	76	12.58	2.75	41.35	238	40.47

Block.	From 25 to 29 feet.		From 30 to 34 feet.		From 35 to 39 feet.		Totals.	
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.
I	25	6.14	5	1.23			407	100
II	155	38.46	6	1.49	1	0.25	403	100
III	15	3.61					416	100
IV	58	11.88					489	100
V	14	2.62					534	100
VI							898	100
VII	9	1.13					797	100
VIII	2	.26					770	100
IX	1	.15					646	100
X							686	100
XI							726	100
XII							589	100
Average	23	5.35	1	.23		.02	613	100

THE POORER TREES REMOVED, THE BETTER ONES TRIMMED UP. PLANTING OF 1890, YAGGY PLANTATION.

TREES WHICH WERE NOT CUT BACK WHEN YOUNG. PLANTING OF 1891, YAGGY PLANTATION.

Many side branches and crooked form the result.

VIGOROUS YOUNG SPROUTS ON THE RIGHT, FROM SCRUBBY TREES CUT DOWN TWO YEARS BEFORE. SPROUTS ON THE LEFT ONLY ONE YEAR OLD. YAGGY PLANTATION.

FIG. 1.—SPROUTS FROM INFERIOR TREES CUT OFF JANUARY, 1901, YAGGY PLANTATION.

FIG. 2.—SAME AS ABOVE, WITH ROWS OF UNCUT TREES LEFT FOR SHELTER BELT IN THE BACKGROUND.

Diameters, Yaggy plantation.

Block.	Under 2 inches.		From 2 to 2.9 inches.		From 3 to 3.9 inches.	
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.
I	29	7.13	99	24.32	186	45.70
II	8	1.99	43	10.67	155	38.46
III	35	8.42	68	16.32	171	41.11
IV	2	.41	21	4.29	159	32.52
V	2	.37	30	5.62	251	47.00
VI	5	.56	232	25.81	523	58.24
VII	7	.88	166	20.83	417	52.32
VIII	6	.78	136	17.66	388	50.39
IX	39	6.03	225	34.78	303	46.83
X	203	29.59	204	29.73	261	38.04
XI	48	6.61	417	57.44	255	35.12
XII	39	6.58	287	48.40	232	39.12
Average	35	5.78	161	24.66	275	43.73

Block.	From 4 to 4.9 inches.		From 5 to 5.9 inches.		From 6 to 6.9 inches.		Totals.	
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.
I	88	21.62	5	1.23			407	100
II	172	42.68	25	6.20			403	100
III	134	32.22	8	1.93			416	100
IV	230	47.03	69	14.11	8	1.64	489	100
V	217	40.64	33	6.18	1	.19	534	100
VI	134	14.92	4	.45			898	100
VII	189	23.71	14	1.76	4	.50	797	100
VIII	206	26.75	33	4.29	1	.13	770	100
IX	75	11.59	5	.77			647	100
X	16	2.33	2	.31			686	100
XI	6	.83					726	100
XII	30	5.06	5	.84			593	100
Average	125	22.45	17	3.17	1	.21	613	100

Volume, Yaggy plantation.

[Five medium-size trees on each block.]

Block.	Heartwood.		Sapwood.		Heartwood and sapwood.		Bark.		Whole tree.	
	Volume.	Per cent.	Volume.	Per cent.	Volume.	Per cent.	Volume.	Per cent.	Volume.	Per cent.
	Cubic ft.		*Cubic ft.*		*Cubic ft.*		*Cubic ft.*		*Cubic ft.*	
I	0.3564	70.89	0.0846	16.83	0.4410	87.72	0.0617	12.28	0.5028	100
II	.4525	69.74	.1054	16.25	.5579	85.99	.0909	14.01	.6488	100
III	.3489	74.62	.0669	14.31	.4158	88.94	.0517	11.06	.4676	100
IV	.4618	70.50	.0859	13.13	.5478	83.63	.1072	16.37	.6550	100
V	.4403	69.77	.0911	14.44	.5315	84.21	.0996	15.79	.6312	100
VI	.3355	72.92	.0617	13.41	.3972	86.33	.0628	13.66	.4601	100
VII	.3920	74.98	.0668	12.78	.4588	87.76	.0639	12.23	.5228	100
VIII	.3544	75.55	.0515	10.99	.4059	86.54	.0631	13.46	.4690	100
IX	.3558	74.93	.0639	13.48	.4197	88.41	.0550	11.59	.4748	100
X	.3026	73.15	.0585	14.14	.3611	87.29	.0525	12.71	.4137	100
XI	.2839	75.54	.0453	12.06	.3292	87.60	.0466	12.39	.3758	100
XII	.2176	66.77	.0649	19.92	.2825	86.70	.0433	13.30	.3259	100
Average	.3585	72.45	.0705	14.31	.4290	86.76	.0665	13.24	.4956	100

RELATIVE AMOUNT OF HEARTWOOD, SAPWOOD, AND BARK.

The trees analyzed on all the blocks except IX, X, and XI show ten years' growth since cutting back. On the blocks named there is but five years' growth. Yet it will be seen from the preceding table that there is almost no difference in the relation between the bark, sapwood, and heartwood. The 5-year-old trees show just as much heartwood in comparison with their volume as the 10-year-old trees, and indeed just as much as the 20-year-old trees in the Hunnewell plantation and the Farlington forest.

A summary of averages in the three plantations shows the following:

Plantation.	Age.	Percentage of heartwood.	Percentage of sapwood.	Percentage of bark.	Total.
	Years				
Yaggy	10	72.45	14.31	13.24	100
Hunnewell	18	71.44	14.24	14.32	100
Farlington	21	73.18	10.96	15.86	100

This shows that the high percentage of heartwood is found even in the very young trees and that practically it is uninfluenced by the rate of growth. The 5-year-old sprouts on Blocks IX, X, and XI of the Yaggy plantation have grown very rapidly, yet they show as much heartwood as the slowest growing trees (Block I) of the Farlington forest. It permits of but one conclusion. In the early growth of the Hardy Catalpa neither age nor rate of growth affects to any great extent the relative amount of heartwood. It is generally recognized that the sapwood of the Catalpa does not greatly resist decay when used in or on the ground. Numerous instances are known both in the

case of young and old timber of the sapwood decaying and leaving the heartwood intact after a few years' usage in the soil. However, since the sapwood forms so small a part of the tree, its decay is of but little importance. The heartwood both of young and old timber shows great longevity in the ground. Bulletin No. 108 of the Kansas Experiment Station shows a photograph of an 8-year-old fence post which had been in the ground constantly for twelve years. The heartwood was still in a perfect state of preservation. Pl. XIX shows a section of a fence post which had been in the ground thirty-eight years. The section was taken right at the surface of the ground where decay is always most rapid. Deeper in the ground this post was perfectly solid. (See also Pl. XXII.) This section, it should be explained, was from an old tree which had made very slow growth.

So far as the durability of its timber is concerned, however, the investigations of the Bureau of Forestry seem to show that it is immaterial whether a Catalpa grows slowly or rapidly. If this is the case there need be no fear that fence posts or telegraph poles will not be durable because they have grown rapidly. On the contrary it will give all the more reason for hastening growth by every possible means so as to get the earliest returns.

A few instances have been mentioned of decay in young timber of the Catalpa, but these seem due entirely to untimely cutting and neglect of proper seasoning before placing in the ground. Handled judiciously, the Hardy Catalpa seems as indestructible in the soil as any other American wood.

PRODUCTS.

Products, Yaggy plantation.

Block.	Posts. First class. Number.	Posts. First class. Value at 11 cents each.	Posts. Second class. Number.	Posts. Second class. Value at 7 cents each.	Posts. Third class. Number.	Posts. Third class. Value at 4 cents each.	Posts. Total. Number.	Posts. Total. Value.	Trees already cut. Number.	Posts already cut. Value.	Total value of block.	Value per acre.	Value per acre of different compartments.
I	202	$22.22	344	$24.08	323	$12.92	869	$59.22	538	$78.28	$137.50	$275.00	
II	284	31.24	452	31.64	321	12.84	1,057	75.72	505	94.88	170.60	341.20	
III	239	26.29	356	24.92	308	12.32	903	63.53	558	109.23	172.76	345.52	[a] $315.21
IV	413	45.43	445	31.15	255	10.20	1,113	86.78	399	70.81	157.59	315.18	
V	395	43.45	445	31.15	349	13.96	1,189	88.56	368	61.03	149.59	299.18	
VI	303	33.33	795	55.65	593	23.72	1,691	112.70	......	......	112.70	225.40	
VII	360	39.60	756	52.92	463	18.52	1,579	111.04	......	......	111.04	222.08	[b] 222.47
VIII	393	43.23	666	46.62	503	20.12	1,562	109.97	......	......	109.97	219.94	
IX	206	22.66	499	34.93	376	15.04	1,081	72.63	......	......	72.63	145.26	
X	108	11.88	513	35.91	464	18.56	1,085	66.35	......	......	66.35	132.70	[c] 115.85
XI	92	10.12	555	38.85	365	16.60	1,012	65.57	......	......	65.57	131.14	
XII	19	2.09	156	10.92	218	8.72	393	21.73	......	......	21.73	54.32	
Total	3,014	......	5,982	......	4,538	......	13,549	......	......	......	......	......	

[a] Planting of 1890. [b] Planting of 1891. [c] Planting of 1892.

Under the table of products are shown for each of the twelve blocks the number and value of posts in the trees now standing, the number and value of the trees already cut, the total value of each block, and the average acreage value of the different compartments. A glance at the last column of the table will show a great difference in acreage value between the different years' planting. The difference is due not so much to age as to soil. By referring to the description of the blocks, it will be seen that the trees on the best soil were planted in 1890, on the next best in 1891, and on the poorest in 1892. Here, as in the other plantations, the more fertile soil gives a marked increase in returns. The difference in value is to be partly accounted for in other ways. It will be remembered that the planting of 1891 was never cut back, so that the trees were limby from the ground up and never attained satisfactory height. Much of the growth was in the form of side branches, and therefore wasted for all practical purposes. This greatly reduced the number of posts and likewise the value of the trees.

The value of the planting of 1892 is slightly reduced, because of the thin planting on the best tract planted that year. This is the 80-acre tract on which Blocks IX, X, and XI were taken and which was planted 3 feet 10 inches by 7 feet. With abundance of room the trees produced so many side branches as to have little prospect of value. After standing five years they were cut back, and their later growth is much improved. There is a good prospect for future returns, but ten years have already passed and the tract has made no returns yet. Whatever may be said in favor of thin planting in other places, it was a mistake in this case.

COST AND VALUE.

The cost of this plantation was given in a general way in Bulletin No. 27 of the Division of Forestry. For the planting of 1890 the cost per acre has been approximately as follows:

Rent of land, twelve years, at $2 per annum	$24.00
Cost of growing seedlings	3.60
Cost of planting	3.20
Cost of cultivation, two years	2.40
Cost of cutting back and sprouting	2.50
Cost of marketing, at 1 cent per tree	20.84
Total	56.54

The cost of the planting of 1891 would be the same except for rent of land, the cutting back and sprouting, and the marketing. Making the proper corrections for these differences, the cost would be $47.64.

In the same way the cost per acre of the planting of 1892, including the cost of pruning or Blocks IX, X, and XI, would amount to $43.36.

A summary of the returns and cost per acre of the different compartments shows these results:

Compartment.	Value.	Cost.	Return.	Average annual return.
Planting of 1890	$315.21	$56.54	$258.67	$21.55
Planting of 1891	222.47	47.64	174.83	15.89
Planting of 1892	115.85	43.36	72.49	7.25

The planting of 1892 includes 125 acres of fair timber, which has a value nearly equal to the planting of 1891, and 100 acres which at the present time has almost no value at all. This is the growth on the sandy land near the river, which was so poor that it was cut down a year ago, and will be reproduced by sprouts. It barely repaid the expense of cutting.

IMPORTANT CULTURAL POINTS.

Some very important facts are made clear in the study of these four plantations, and though already mentioned, they are brought together here for the sake of giving them special attention.

(1) It is shown in each plantation that the Hardy Catalpa reaches its best growth only on very rich soil. In the Farlington Forest the returns on the best soil are almost five times as great as on the poorest. The Yaggy plantation, which shows great variation in soil fertility, has given no return on poor sandy soil, while on rich loam it has given a clear annual profit of $21.55 per acre.

Depth and porosity are as important as fertility. The trees do not thrive unless their roots penetrate well into the ground. An impervious layer of clay near the surface is prohibitive of successful growth. If the clay is not too dense, however, and occurs beneath several feet of good soil, it is highly beneficial, as in that case it forms a foundation for the soil and retains fertility and moisture. Portions of the Yaggy plantation illustrate this point excellently.

(2) Grown in pure stand or mixed with trees no taller than itself, and especially in plantations on the plains, the Catalpa should be protected from prevailing winds by shelter belts of taller trees. The damaging effect of wind is to be seen more plainly in the Munger plantation than in the others described, but it is evident in the others and indeed in almost every unprotected plantation in the Middle West. A thin belt of Cottonwood on the windward side of a plantation will protect the edge trees and allow them to make much taller and straighter growth. Even an Osage Orange hedge, though not growing so tall as the Catalpas, will greatly protect them, as the Munger plantation shows.

(3) It is much cheaper for the planter to grow his trees from seed than to buy them from a nursery, if a large number are to be planted. In the Munger plantation the cost of trees grown on the farm was 50 cents per thousand, while those from a nursery with freight cost about $4 per thousand. The cost of establishing the Yaggy plantation with home-grown trees, including cutting back and two years' tillage, was $11.70 per acre: the cost of establishing the Farlington Forest by contract, including the same amount of tillage but no cutting back, was $30 per acre. Such differences in initial cost count up immensely on final profits in long investments like forest-tree growing. It is good business sense to reduce the first cost of forest planting of any kind to the least possible amount.

(4) Three of these plantations were planted 4 by 4 feet, thus giving 16 square feet to each tree: the other was planted 3 feet 10 inches by 6 feet, which gives each tree 23 square feet. While the Hunnewell and Farlington plantations became densely crowded when 10 or 12 years old, and were not thinned according to their needs, there is not the slightest reason for believing that they were planted too thick. Had they been planted thinner, neglected as they have been, they would have been in far worse condition than they are. Fewer trees would have died and the living ones might have had larger diameters, but they would have been lower and so much branched from the ground up as to be utterly worthless for any other purpose than short fence posts. Without severe crowding the Catalpa will not produce the straight pole growth necessary for best use. With plenty of room it is a spreading round-topped tree with almost no tendency toward an elongated central axis, and pruning, while it may somewhat improve the form, will not sufficiently change it to make the tree of much use. At best, pruning can only remove the branches within 8 or 9 feet of the ground. Above that height it is entirely impracticable in a commercial plantation.

The Catalpa planter who sets his trees thinly upon the ground will find them growing with spreading tops in spite of his most careful efforts to prevent it.

The most important advantage of close planting for the Catalpa is that it kills the lateral branches while young. If the lateral branches die before becoming more than one-half inch in diameter, they are easily pushed off by the tree and do no damage, but if they reach a larger size than this, as they are sure to do in thin planting, they cling to the tree for years, even after they die.

(5) The development of large side branches unfits the Catalpa for practical use. While the stand may become so dense as finally to shade them out, they cling with such persistence to the growing trunk that it can not cast them off. New wood is deposited around the dead branches, but does not unite with them. The holes thus formed lead straight into the heart of the tree, and the angle of the branches is

just right to conduct water and germs of decay into the trunk. When the branch is finally released, it leaves a great hole leading to the decayed heart of the tree. (See Pl. VI, figs. 1 and 2.) The tree thus ruined sooner or later breaks down, a complete loss. Even in the close-planted Farlington Forest a considerable loss has been sustained in this way, as referred to on page 17; and where the planting is thinner and side branches more abundant and larger, a still greater loss can not easily be avoided.

(6) The cutting back of the young trees after two or three seasons' growth from planting, and the training up of a single sprout from the stump greatly hastens height growth and prevents side branches on the lower part of the trunk. The season following the cutting back a numerous brood of sprouts will spring up from the stump, all of which, except the most vigorous one, should be removed. The survivor will make a straight, branchless growth of from 8 to 10 feet the first season. In its growth the following year it will produce side branches, but not on the growth made the first year. The main advantage of cutting back is that without retarding height growth, it prevents side branches to a height of from 8 to 10 feet. It accomplishes the same object as pruning at a much less expense.

(7) With close planting and cutting back two years thereafter, thinning will become necessary within eight or ten years from the time of planting. Some of the trees will be large enough for fence posts, and both the Munger and the Yaggy plantations show that if the work is judiciously done good returns may be secured from this first cutting. Wherever there is a demand for small posts and firewood, the grower may expect considerable returns from the thinning of a 10-year-old plantation. If the growth is satisfactory it usually will be best to cut out the defective and suppressed trees. In this thinning the stand may be reduced to 1,200 or 1,300 trees per acre, consisting of the straightest and best, though not necessarily the largest trees.

(8) When the first growth is for any reason bushy and undesirable, a better growth can usually be secured by cutting the stand clean and reproducing it by sprouts. This was demonstrated in the Yaggy plantation on Blocks IX, X, and XI, and also in the Munger plantation where the first growth in places was practically a failure on account of a hardpan soil. Pl. III, fig. 2, and Pl. XVIII show reproduction on strips clean cut in this way.

(9) A clean-cut stand should be protected by occasional strips of timber left uncut for the protection of the succeeding crop of sprouts. This is especially necessary on the prairies where heavy winds prevail, for the young sprouts are very tender and easily broken off during the first year or two of their growth. The protective strips are best run east and west, as the most damaging winds are from the south.

(10) The best growth of Catalpa is not obtained in pure plantations. This statement is contrary to general practice and belief, for almost all Catalpa plantations throughout the country are pure planted, and a majority of planters would hesitate to admit that a better method is to be found. This opinion prevails because the tree has so seldom been tried in proper mixtures. Some have never seen it so tried, and therefore doubt its success.

The peculiar advantage of an associate tree is to supply undergrowth, and its effect would be seen in the following two ways:

(*a*) In shading the ground, thereby keeping it cool, retaining moisture, and preventing the entrance of injurious weeds and grasses.

(*b*) In growing up immediately under the crowns of the Catalpa, forcing the top upward and killing off the side branches while young, so that a long, straight, clean bole may be secured at least to a height of 18 to 20 feet. With cutting back and the use of the proper associate tree, side branches can practically be dispensed with.

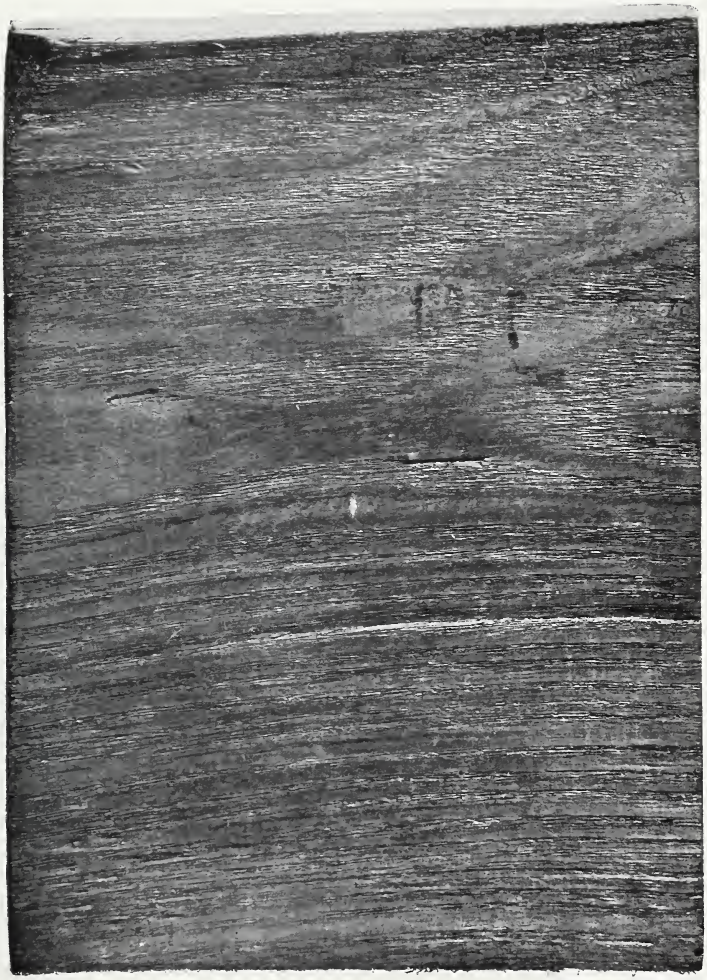
Not many trees are adapted to this purpose, and when the further requirement is made that they themselves shall have some commercial value, the list becomes very brief. In the middle West the two trees best suited for the purpose are the Osage Orange and Russian Mulberry, both of which are adapted to about the same range for planting as the Hardy Catalpa.

(11) A high percentage of straight, limbless poles can not be secured from the Catalpa without the most careful treatment. As has been explained, it has a strong tendency toward crookedness, and its tendency toward branching will always prevent a clean bole unless it is overcome. It therefore requires close attention to be fully successful. It must be cut back when young and then crowded into straight, tall growth by its own dense stand or proper mixtures. Some pruning may still be required, and even then not all the trees will have the form to make telegraph poles. Yet it pays to give these attentions, for experience shows that the planters who have done so have received relatively more for their labor than those who have allowed the trees to grow in their own way.

(12) The heartwood of the Hardy Catalpa forms nearly three-fourths of the volume of the entire tree, even at the early age of 5 to 10 years, and is durable in the soil if properly seasoned, regardless of age and rapidity of growth. Growers need not, therefore, hesitate about forcing the growth of their plantations as much as possible, nor does experience give them ground to claim a higher value for their products because they have grown slowly. The rate of growth will make no difference in the sale of the products whether they be posts, poles, or ties. Only shape and size will count. The intelligent grower will look for land and methods which will give the best growth and most perfect form in the least time. Upon these alone will profits depend.

SECTION, TAKEN AT THE SURFACE OF THE GROUND, OF A HARDY CATALPA FENCE POST WHICH HAD BEEN SET THIRTY-EIGHT YEARS.

The cavities show the work of termites.



WOOD OF THE HARDY CATALPA AFTER LYING NINETY YEARS IN WATER.

Block from a tree which grew near New Madrid, Mo., and was felled by the earthquake of 1812. It was taken out of the water a short time ago and worked into fence posts.

Catalpa Tie, Eighteen Years' Service.

FENCE POSTS OF CATALPA, THIRTY-EIGHT YEARS' SERVICE.

II. DISEASES OF THE HARDY CATALPA.

By Hermann von Schrenk,
Bureau of Plant Industry.

INTRODUCTION.

The Hardy Catalpa is, as a rule, a tree singularly free from destructive diseases. A number of parasitic fungi grow in the living leaves, where they may do considerable harm, especially during moist, warm summers. They are rarely present in sufficient numbers, however, to cause alarm. The young twigs are rarely attacked by any fungous disease, so far as has been determined. Root-rot diseases are likewise unknown. The wood of the trunk, under unfavorable conditions, considered more in detail below, is destroyed by two fungi, both of which do considerable harm.

DURABILITY OF CATALPA TIMBER.

Catalpa wood, after it is cut from the living tree, is one of the most durable timbers known. In spite of its light porous structure it resists the weathering influences and the attacks of wood destroying fungi to a remarkable degree. So far as the writer has been able to determine, none of the ordinary saprophytic wood-destroying fungi grow in Catalpa wood; in fact no fungus has yet been found which will grow in the dead timber. This is certainly a very remarkable fact, and worthy of the utmost consideration. After long exposure to weathering influences, which may mean twenty to thirty years and more, portions of the wood do change and crumble away. To what these changes are due it is difficult to say at this time. It may be that the alternate wetting and drying of the wood fibers, causing expansion and contraction for long periods, finally bring about changes in the fiber. These changes are so small, however, that for practical purposes they can be disregarded.

There is now no longer any question as to the long-lasting powers of this wood. Engineers who employed the wood in railway construction in southern Illinois and Missouri, many years ago, when the original groves of Catalpa trees were still standing, were well aware of its valuable properties. In an interesting pamphlet Mr. E. E. Barney[a]

[a] Barney, E. E.: Facts and Information in Relation to the Catalpa Tree. Dayton, Ohio, 1878.

MICROSCOPIC CHANGES.

In the discolored areas, which represent the first stages of the disease, the fine medullary rays are filled with a yellow substance, apparently decomposition products. The only change noticeable in the wood cells proper is a gradual shrinking of the walls (see figs. 1 and 2). This shrinkage goes on so evenly that no cracks or breaks are visible. In wood which is in an intermediate stage, the walls of the fibers are very thin, scarcely half as thick as in the healthy fibers.

FIG. 1.—Wood cells from sound Catalpa timber.

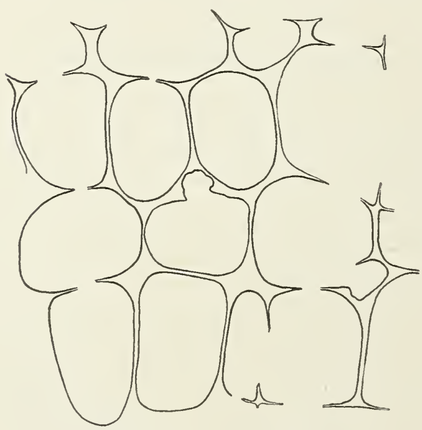
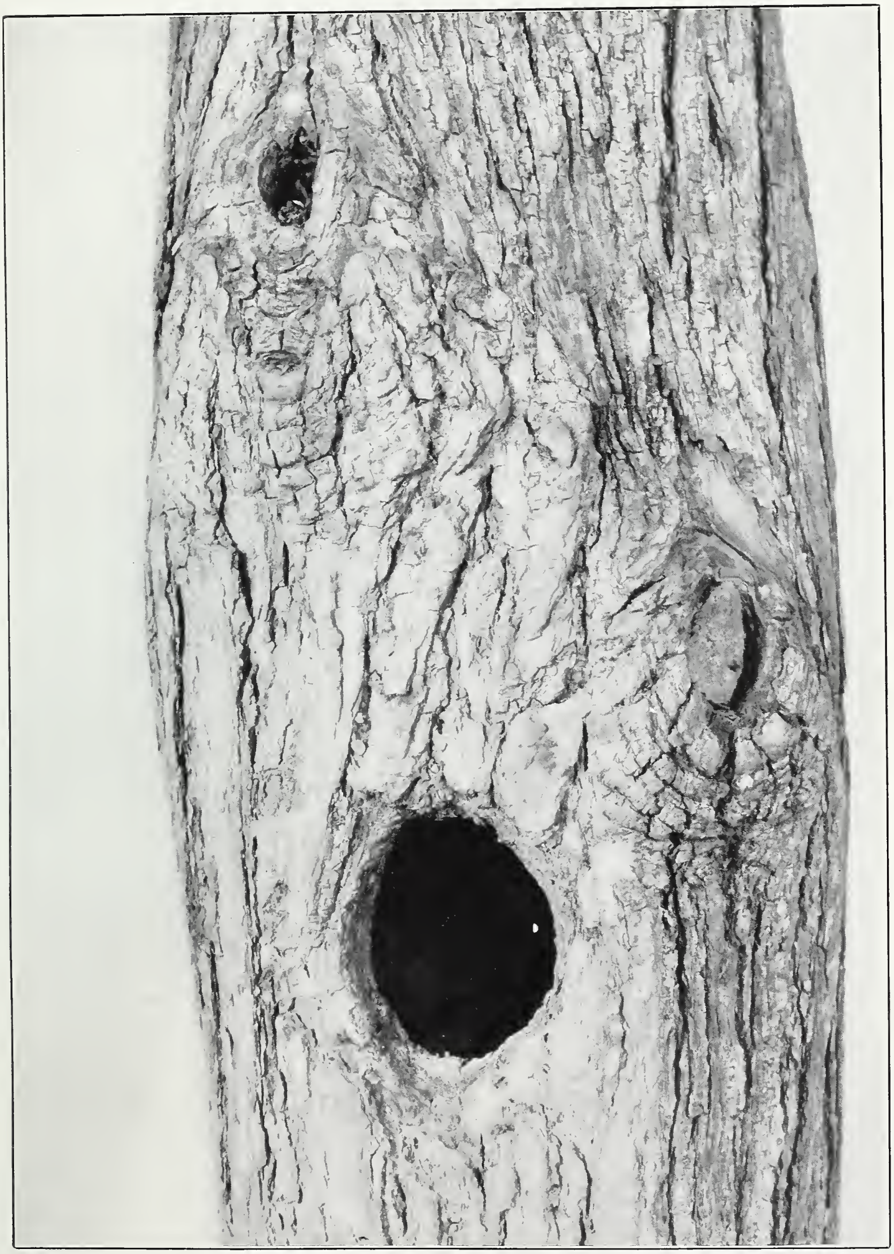


FIG. 2.—Wood cells from decayed Catalpa timber.

These diseased cells do not swell with potash. They retain their lignin characteristics, staining with phloroglucin, and also with permanganate of potash and ammonia. In the last stages, at points where two cells meet, the walls are dissolved entirely, leaving pieces of more resistant wood here and there. An entire dissolution rarely takes place. The exact steps which take place in this process are of less interest at this time, and will be described more fully in another publication.



CATALPA TRUNK, SHOWING WOODPECKER'S NEST IN DISEASED WOOD.

Diseased Catalpa Tree Broken off by Wind; Fungus Growing on the Trunk.

Fig. 1.

Fig. 2.

EARLY STAGES OF CATALPA DISEASE.

Fig. 1.

Fig. 2.

LATER STAGES OF CATALPA DISEASE.

GROWTH OF THE FUNGUS.

Polyporus versicolor spreads from tree to tree by spores. The spores germinate probably in the cavities left when branches rot away (Pl. XXVII, fig. 1), as described below, also in wounds made when trees are pruned (Pl. XXVIII). The fungus hyphæ grow down the branch and from its base spread both up and down the trunk. Growth takes place with considerable rapidity, for it was found that the fungus had decayed trees injured only six to seven years before. All woody parts of a tree are attacked. The tree figured on Pl. XXIV was diseased for 20 feet up from the point of infection, near the base of the trunk, and three of the large roots were decayed at the center. When a sufficient amount of material has been removed from the wood the fruiting bodies form on the old stump (Pl. XXVIII) or on the bark.

INFECTION.

The number of trees affected by the disease in the Farlington grove is comparatively large, because of the great number of dead limbs which cling to the trees. The cultivation of the trees in close blocks, while necessary to make the trunks grow straight and tall, causes the death of any side branches which may grow and facilitates destruction by this fungus disease when proper precautions are not taken.

When the Catalpa grows by itself it forms a rounded head, supported by a short trunk. Most of the branches which form from time to time remain on the tree (Pl. XXIX and Pl. XXVII, fig. 3) as growing parts. It is very rare for a branch to die on a vigorous tree. When grown close together, as at Farlington, the trees crowd one another, and after several years the shade cast by the tops above is so great that the lower branches are killed. These branches vary in thickness from one-fourth inch to an inch. They remain on the tree for many years, and as the tree grows in thickness the base of these branches is gradually surrounded by the trunk. (Pl. XXVII, fig. 1.) After the death of a branch all growth of its base ceases, so that with subsequent growth of the trunk no union between the newer wood of the trunk and the wood of the branch base takes place. In the Farlington forest these dead branches stand out at an angle of about 45 degrees (Pl. XXIX), and the striking part is that so few have apparently broken off. When bent down a foot or more out from the trunk these dead branches do not break off as a rule, showing that there is nothing resembling the bark pressure of many other forest trees. The wood at the base of the branch is tough and twisted. When the branch finally does break, it breaks within the trunk. (Pl. XXVII, fig. 1.) This leaves a small hole (Pl. XXIII, upper part), in which water and dust collect. Such a hole forms an admirable starting point for the

fungus described, if indeed it has not already started before the branch is released.

The branches which decay first are near the ground, and gradually one or more of the branches farther up decay so as to fall off. It ought to be said that it was observed that in most trees at Farlington the number of branches which did fall off because of decay at the base was very small, but enough fall off from every tree to make it noticeable. This was in trees about twenty years old.

THE FUNGUS.

The fungus causing the soft rot of living Catalpa trees is one of the higher forms belonging to the Polyporeæ (*Polyporus* (*Polystictus*) *versicolor* (Linn.) Fr.) (Pl. XXVIII.) The varicolored fruiting bodies of the fungus form in old knot holes or on dead stumps during the latter part of the summer. This fungus is very common on dead wood of all kinds, particularly on the various kinds of Oak, on Sycamore, Maple, Beech, etc. It never grows, so far as is now known, on live trees. The sessile sporophores grow many together, one above the other. They are readily recognized by the soft, hairy upper surface, formed by bands of several colors. The margin of the sporophores are irregularly wavy when dry. Fresh sporophores are fleshy, but as they grow older they become tough and somewhat brittle, and the front edge curls in. In spring a number of beetles eat the hymenial layer, so that by June little is left of the older sporophores.

The mycelium of this fungus is extremely fine and almost colorless. In newly infected wood it is barely visible. Now and then it forms sheets of variable thickness in decayed wood, but this is rather exceptional.

The sporophores were found only on living trees. In the woods, diseased trunks were found, which had been lying on the ground for four years. The fungus had not formed any fruiting bodies, as is so often the case with other fungi. There was, moreover, no sign of the decay having continued in the trunks after the latter had been cut. This is a fortunate circumstance for the farmer, because it does not make a post partially diseased wholly worthless. The writer is fully convinced that posts diseased in the center, although not as strong as sound posts, will nevertheless last a long time, and ought not to be discriminated against too severely. That is, the fungus which destroys the wood while it is a part of the tree stops its growth when that tree is cut.

We have here a curious case of close adaption. *Polyporus versicolor*, a fungus which usually grows only on dead wood, i. e., wood cut or broken from the tree, here grows only in the wood of the living tree. The dead wood of the Catalpa is as resistant to the mycelium of

Polyporus versicolor as it is to that of any other fungus. In the Mississippi Valley there is every chance for infection of the Catalpa wood used for fence posts or ties, for *Polyporus versicolor* is one of the commonest fungi in the woods, on old stumps, on railroad ties, etc.

REMEDIES.

From the foregoing it becomes very evident that in order to prevent the decay of the trunks it will be necessary to prevent the entrance of the fungus spores. There is probably no tree where this can be done with so much guaranty for success as the Catalpa, and there is absolutely no reason why these trees should be diseased. The treatment of trees planted for timber will warrant using methods which would not be justifiable in the forest. This means that the Catalpa when grown close in stand, as in a commercial plantation, will have to be treated to prevent the growth of side branches, and where that is not possible, pruning will have to be resorted to. The trees should be cut back when young, as discussed in Part I of this bulletin, and wherever possible they should be grown in mixture with other trees which will crowd their tops upward and kill off the side branches while small.

Even with this treatment some pruning may be necessary. This should be done with a saw or sharp ax. The branches should be cut as close to the trunk as possible without injuring the bark. (Pl. XXVII, fig. 2.) In the case of the larger branches, care should be taken to make a cut on the under side of the branch before the upper side is cut into. Pruning may be done during the late fall and winter; the water content of the wood is then at the lowest point, which makes the operation an easier and a safer one than in spring or summer; it is, likewise, a time when labor can be most readily spared.

COATING OF WOUNDS.

After cutting off a branch care should be taken to coat the wound with some antiseptic substance. Ordinary coal tar is the most effective substance for this purpose. It is cheap, can be purchased anywhere, and is easily and rapidly applied. It has the great advantage of penetrating the wood for some distance, and in so doing it fills the pores of the wood and penetrates into the fiber itself; that is, it combines with the wood, and no amount of rubbing or weathering can destroy it. It can not be applied to green or wet wood. Coal tar is a powerful antiseptic. It prevents the growth of fungi entirely. It is, furthermore, a good substance to keep boring insects at a distance. The latter are often instrumental in making passageways through which water and fungus spores can enter. The wood of the Catalpa being porous, it absorbs the coal tar with great readiness, as experiments at Farlington demonstrated. It took but a few seconds for the dry wood to

absorb the coal tar. The coal tar is most readily applied with a small paint brush. The coal tar ought to be very liquid, and if sticky or thick, as is often the case in winter, it should be warmed before applying. The person who does the pruning ought to carry a can, with a small opening, full of tar oil slung by a strap over one shoulder. Wherever a cut is made the coal tar should be applied thoroughly. If conducted in this way the operation takes very little time.

When properly pruned and protected a wound heals rapidly, and after the callous parts have united all danger from fungus infection is removed. It appears from the foregoing, therefore, that this disease is absolutely preventable. Even in their present condition many of the trees at Farlington could be saved. All healthy trees should be pruned at once. Broken branches or old wounds should be coated, for many of these branches (even those three and four years old) are still uninjured and have begun to heal.

Trees with holes at one or more points should be cut at once and utilized.

COST OF PRUNING.

The recommendations made above are made without reference to the cost of these operations, as it was impossible to get even approximate figures. The pruning will be possible only for branches which can be reached from the ground, as it would not pay to prune the upper branches. Parts of the Farlington plantation will be pruned this year to determine the practicability of such operations.

BROWN ROT.

A second form of wood decay was noted in some Catalpa trees which is very different from the one just described. The wood, instead of becoming a straw-yellow color and somewhat tough, is brown, very brittle, and full of cracks. (Pl. XXX.)

OCCURRENCE.

The trees affected with this disease were found at Farlington, Kans., and in southern Missouri.

MANNER OF OCCURRENCE.

All trees found were decayed near the ground. The decay extended up into the trees for some distance, but never more than 10 feet. The extent to which the trunk was decayed differed. In several instances only the center of the tree was affected (Pl. XXX, fig. 1), while in others not only was the center entirely rotted, but also the sapwood

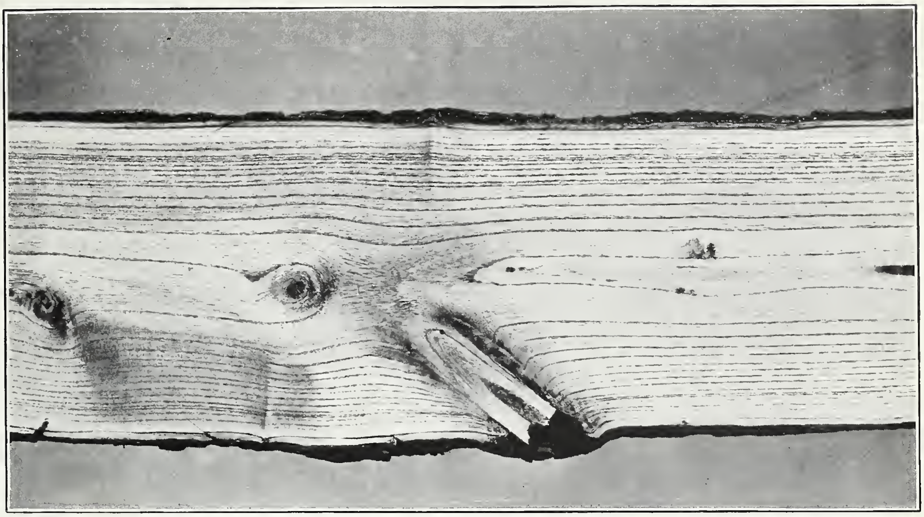


FIG. 1.—SECTION SHOWING HOW A DEAD BRANCH ROTS AWAY.

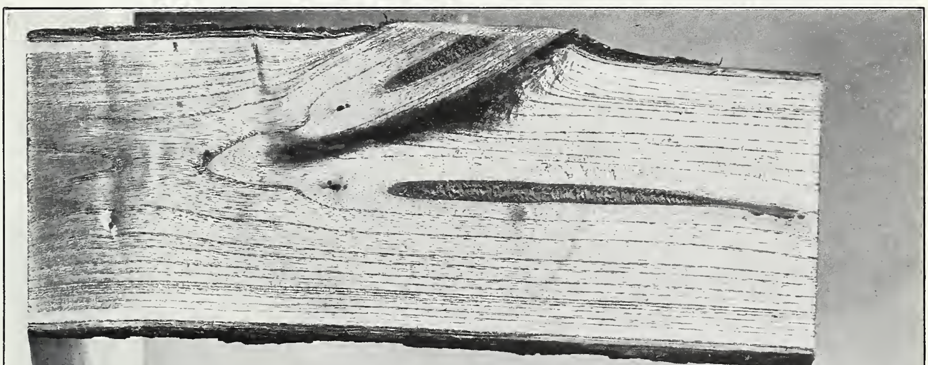


FIG. 2.—HOW TO PRUNE A DEAD BRANCH.

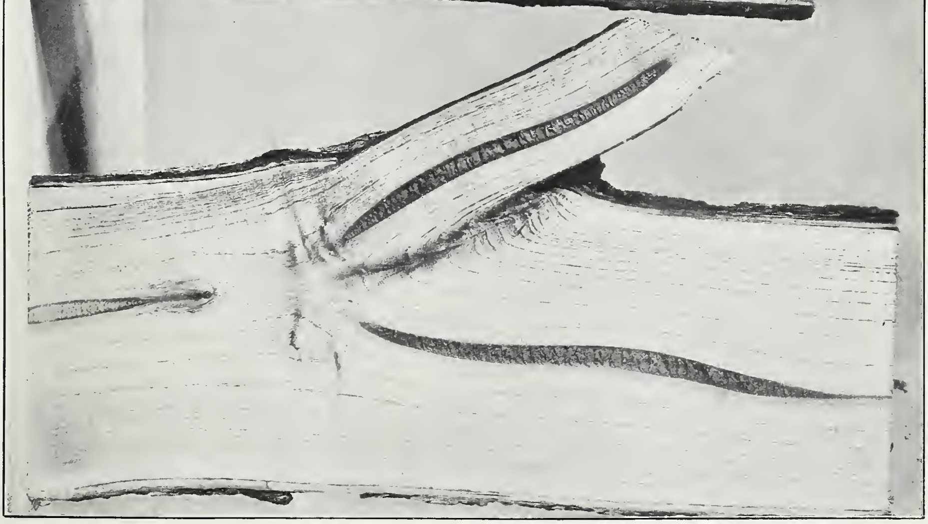
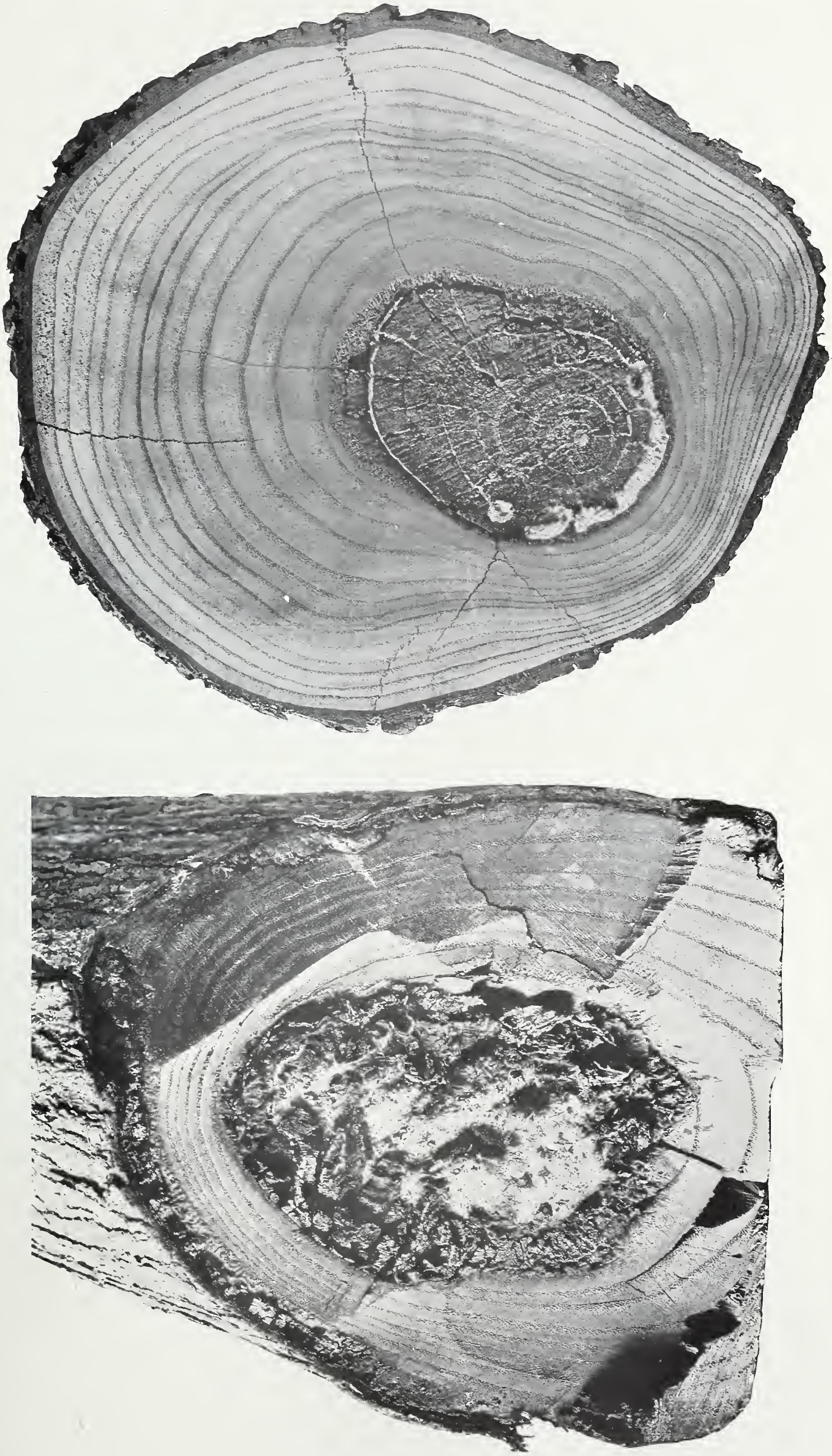


FIG. 3.—SECTION OF DEAD BRANCH.

POLYPORUS VERSICOLOR CAUSING SOFT ROT.

CATALPA TREES, SHOWING HOW DEAD BRANCHES REMAIN ON THE TREES.



BROWN ROT OF CATALPA.

clear out to the bark (Pl. XXX, fig. 3). The rot extended down into the larger roots for some distance. In this disease, as in the soft rot, it was noted that the distinction between heart and sapwood was not very sharp—that is, there seemed to be little difference between the rate of decay of the outermost rings and those farther in. Trees in which decay had progressed to any extent were usually broken off close to the ground. The decay then continued for some time after the tree had fallen.

APPEARANCE OF WOOD.

The first changes noticeable in the sound wood appear in the spring wood, where the vessels become lighter in color. The summer wood gradually becomes paler and then all at once the whole wood ring loses its hard character. Cracks appear here and there, especially along the lines separating the annual rings of wood. In time these cracks are filled with spongy masses of mycelium, which sometimes reach considerable proportions. (See lower part of fig. 1, Pl. XXX.) The completely rotted wood has many of the properties of charcoal. It is red-brown, very light, exceedingly brittle, crumbling into a fine powder when pounded, and has none of the pungent odor of sound wood. It absorbs water readily, and when wet cuts like cheese. Examined microscopically, one finds that the fungus hyphæ absorb the cellulose parts of the wood fiber. This results in considerable shrinkage of the walls. Treated with potassium hydrate, the latter turn bright yellow and swell to several times their normal size. These changes resemble the carbonizing of other woods, induced by the mycelia of such fungi as *Polyporus sulphureus*, *Polyporus schweinitzii*, etc. It differs from this carbonizing in the complete absence of spiral or longitudinal cracks in the walls of the wood fibers.

FRUITING BODY.

The fruiting bodies of *Polyporus* (*Poria*) form on the bark of diseased trees where the decay has extended out through the sapwood. They are found also in cracks and on decayed wood at the point where the diseased trees have broken off. (Pl. XXX.) The fruiting organs consist of flat sheets closely oppressed to the bark on decayed wood. The sheets adapt themselves to the form of the substratum, so that in a broken trunk one will find the fruiting surfaces coating wood pieces of all shapes and sizes. These sheets are white when young, turning yellow and finally brown. Older sheets are much cracked because of drying. The pores are about one-eigth of an inch deep. They are rounded at first, and when old they are more or less angular, with a roughened margin. The form is so variable that it is difficult to

assign it to any one species. It resembles *Polyporus* (*Poria*) *vaporarius* somewhat, but is dark brown. For the present it may be designated as *Polyporus* (*Poria*) *catalpæ* n. sp.

MODE OF GROWTH.

This fungus is also a wound parasite, as far as could be determined. In the majority of cases it had evidently entered through the wound made some ten years ago, when some larger branches were cut off close to the ground. (See Pl. XXX.)

PREVENTIVE MEASURES.

Measures which will prevent the entrance of spores of *Polyporus versicolor* will do so for the brown-rot fungus, also. There is, therefore, no necessity of repeating those directions here.

SMALL DANGER OF SPREAD.

The brown rot was found only locally and then only here and there. It is by no means as dangerous a parasite as *Polyporus versicolor*, and with a little care can probably be prevented entirely. Trees with the center partially rotted will serve as posts, for there does not seem to be any danger that decay will continue on after the trees are cut.

BLIGHT DISEASE.

The young shoots and leaves of the Catalpa frequently suffer from an apparent blight. The leaves and buds turn black, shrivel, and drop off. The trouble is widely distributed all over the Western country. It is caused by the larvæ of Diplosis, one of the gall-gnats. The injury is one which may be very severe. Trees that are attacked several years in succession show evidences of the injury in the profuse production of small branches and a general shortening of the branch system.

During the past spring numerous larvæ were found on the affected leaves, concerning which Dr. L. O. Howard writes:

> They are the larvæ of the species of Triphleps, which prey upon the Diplosis. The Triphleps is so numerous that perhaps it will correct the trouble.

O

VIRGIN REDWOOD ALONG SOUTH FORK OF EEL RIVER.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF FORESTRY—BULLETIN No. 38.

GIFFORD PINCHOT, Forester.

THE REDWOOD.

I. A STUDY OF THE REDWOOD.

By RICHARD T. FISHER, *Field Assistant, Bureau of Forestry.*

II. THE BROWN ROT DISEASE OF THE REDWOOD.

By HERMANN VON SCHRENK, *Bureau of Plant Industry.*

III. INSECT ENEMIES OF THE REDWOOD.

By A. D. HOPKINS, *Division of Entomology.*

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Forestry,
Washington, D. C., November 18, 1902.

Sir: I have the honor to transmit herewith a manuscript on "The Redwood," by Richard T. Fisher, Field Assistant, Bureau of Forestry, together with a discussion of "The Brown Rot Disease of the Redwood," by Dr. Hermann von Schrenk, of the Bureau of Plant Industry, and of "Insect Enemies of the Redwood," by Dr. A. D. Hopkins, of the Division of Entomology, and to recommend its publication as Bulletin No. 38 of the Bureau of Forestry.

In the summer of 1899 several prominent manufacturers of the Pacific coast requested that the Division (now Bureau) of Forestry make a study of the Redwood. They contributed $550 toward the expense of the work, and offered the hospitality of their camps to the agents who should have it in charge. The Division put a party in the field, which in six months during the years 1899 and 1900 examined nearly all the Redwood belt. Studies of old timber were made at Fort Bragg, Mendocino County; at Scotia, Humboldt County; at Ryan's Slough, near Eureka; at Vance's, on Mad River; and at Crescent City, Del Norte County. Second growth in small areas was studied at Crescent City, Trinidad, Eureka, and Arcata. For courtesies received in lumber camps at these places acknowledgment is made.

The illustrations, which include thirteen full page plates, four text figures, and two diagrams, are considered essential for a proper understanding of the text.

Respectfully,

Gifford Pinchot, *Forester.*

Hon. James Wilson,
Secretary of Agriculture.

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THE REDWOOD.

A STUDY OF THE REDWOOD.

By Richard T. Fisher,
Field Assistant, Bureau of Forestry.

SCOPE OF THE STUDY.

This study concerns itself with young second-growth Redwood rather than with mature trees; with lumbered areas rather than with the virgin forest. Where attention is given the old forest and methods of lumbering, it is only that a better knowledge may be gained of second growth and how to deal with it.

. An attempt is made to answer the question whether it would prove profitable to hold cut-over Redwood lands for future crops. To save the young growth when the old timber is lumbered and to protect the cut-over lands from fire can not be done without cost. The problem, then, more plainly presents itself: Does the Coast Redwood reproduce itself well enough, grow fast enough, and can it be protected cheaply enough to make it profitable to hold the lands?

CONCLUSIONS REACHED BY THE STUDY.

The following facts have been determined:

That the Redwood reproduces itself abundantly by sprouts on cut-over lands, and occasionally by seed;

That in thirty years, in a fair soil and a dense stand, it will produce trees of 16 inches diameter, 80 feet high, yielding 2,000 feet board measure per acre; and

That after careful lumbering under favorable conditions it does pay to hold cut-over Redwood lands for future crops.

INTRODUCTION.

In order to deal with a tree so as to make it produce as much wood as possible in the shortest time, it is necessary to know a great deal about its silvicultural habits. This includes a knowledge of its soil and moisture requirements, the climate and altitude it prefers, its

ability to grow in the shade, and, most important of all, its rate of growth under different conditions.

Serious difficulties lie in the way of obtaining such knowledge of the Redwood. If fully exposed, the tree makes a surprisingly rapid growth: if suppressed, it may exist for a hundred years with but slight increase in diameter, only to take on new life when again exposed and to grow like a sapling. The Redwood forest is so dense that, according to the methods now in use, to lumber it is to annihilate it. Since the reproduction starts up under conditions entirely different from those that prevailed in the old forest, its rate of growth will vary. It is evident that the rate of growth of young timber can not be forecasted from that of old trees, and that trees, to furnish material for yield tables, must have been growing under the same general conditions as those trees to which the tables are to be applied.

The old Redwood will inevitably be cut. Occasionally, it is true, parks and recreation grounds may preserve, on small areas, examples of this wonderful forest growth, but generally the Redwood must be lumbered on account of its commercial value. Since it is with the Redwood as a timber tree that the present study is concerned, the question of preserving it for its beauty is necessarily outside the purpose of the discussion.

But while the old forest must be lumbered, it is important that the lumbering should be less destructive to the young trees. Difficult as logging is among the great Redwoods, it need not mean the total destruction of the forest. Better methods than those now in use must soon be found possible and profitable. In support of this prediction may be cited the case of the Mendocino Lumber Company, an account of whose operations is given in this bulletin. This company has furnished very valuable lessons in Redwood forest management, and has gone far to solve the problem of providing for second growth on Redwood lands. By exercising care in cutting, it has secured splendid stands of second growth on land which, had it been lumbered by the ordinary methods, would be now almost valueless.

FOREST DESCRIPTION.

THE REDWOOD AND THE BIG TREE DISTINCT SPECIES.

The Redwood of California (*Sequoia sempervirens*) belongs to a genus of which the Big Tree (*Sequoia washingtoniana*) is the only other species now alive. Both are allied to the Cypress (*Taxodium distichum*), and their lumber is often called by the same name, but they are botanically distinct from each other. They do not even occupy the same situations. The Big Tree occurs in scattered bodies on the west slopes of the Sierra Nevada, while the Redwood forms dense forests on the west slopes of the Coast Range.

FIG. 1.—REDWOOD SLOPE, SOUTH FORK OF EEL RIVER.

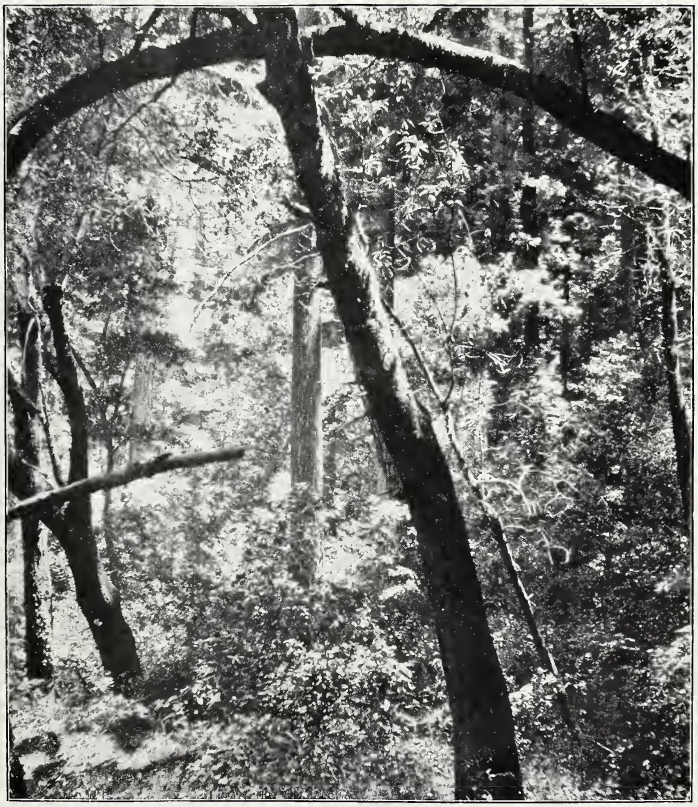

FIG. 2.—REDWOOD SLOPE, BIG BASIN, SANTA CRUZ MOUNTAINS.

FIG. 1.—REDWOOD FLAT, ALLUVIAL BENCHES, SOUTH FORK OF EEL RIVER.

FIG. 2.—REDWOOD FLAT, CRESCENT CITY.

FIG. 1.—TYPICAL FORMS OF MATURE REDWOOD, CRESCENT CITY.

FIG. 2.—CHARACTERISTIC SPROUTING OF BROKEN REDWOOD.

FIG. 1.—SPROUTS OF ONE SEASON'S GROWTH, CRESCENT CITY.

FIG. 2.—SPROUTS 6 TO 8 YEARS OLD, CRESCENT CITY.

DISTRIBUTION OF THE REDWOOD.

The Redwood is popularly thought to occupy a strip of country 10 to 30 miles wide, from the Oregon line to the Bay of Monterey, but these boundaries do not cover its actual distribution. Two thousand acres of Redwood, in two separate groups, are growing in Oregon along the Chetco River. South of the Chetco a continuous Redwood belt begins. By way of the river valleys and lowlands it increases its width from 10 miles, at Del Norte County, to 18 or 20 miles, and keeps on unbroken to southern Humboldt County. Here, for about a township, it thins out, but becomes dense again 6 miles north of the Mendocino line, and after entering that county widens to 35 miles, its greatest width. The Redwood belt ends in Mendocino County, but isolated forests of the species are growing in sheltered spots as far south as Salmon Creek Canyon, in the Santa Lucia Mountains, Monterey County, 12 miles south of Punta Gorda, and 500 miles from the northern limit of the tree along the Chetco River.

CLIMATE AND TOPOGRAPHY.

The climate and topography that have brought about this limited distribution of the Redwood deserve attention. North and south along the coast, in nearly parallel ridges, lie the mountains of the Coast Range, steep and rising to altitudes of 1,000 to 2,000 feet. A few large rivers and many smaller streams cut through them to enter the sea, and along their courses in places are broad bottom lands and gentle slopes. West of the Coast Range the climate is even and moderate, with a range from just below freezing to 80° F., and a yearly average of from 50° to 60°. Snow lies on the tops of only the highest ridges. Thirty to 60 inches of rain falls in the autumn and winter, and in the summer sea fog bathes the coast. But east of the mountains, less than 50 miles from the sea, lie hot interior valleys, never visited by the fog, parched and rainless in the summer, and wet only occasionally by the winter rains—conditions too unfavorable to permit the growth of the Redwood.

SILVICULTURAL TYPES.

The Redwood may be considered in two types—Redwood Slope and Redwood Flat. It passes from one to the other as the ground becomes steep and dry or level and moist, and admits other species wherever the situation satisfies their requirements.

THE REDWOOD SLOPE.

The common type is the Redwood Slope (Pl. I). It occurs on the steep sides of the Coast Range, and is a mixture of Redwood, Red Fir, Tanbark Oak, and White Fir, with an occasional Madroña or Hemlock.

The Redwood is the predominant tree in the mixture, and the Red Fir ranks next.

The composition of the forest is shown in the following table, which is constructed from surveys taken in six localities. Scotia and Dyerville, since they showed similar conditions, were thrown together. In accordance with the custom of the country, timber with a diameter of 20 inches breasthigh is classed as merchantable.

TABLE 1.—*Redwood Slope.*

Locality and species.	Trees 4 inches and over in diameter breasthigh.		Trees 4 to 19 inches in diameter breasthigh.		Trees 20 inches and over in diameter breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breast-high.
CRESCENT CITY.							*Inches.*
Hemlock	35.24	37	33.11	50	2.13	7	26
Redwood	32.71	34	9.73	15	22.98	79	71
White Fir	15.25	16	14.11	21	1.14	4	30
Red Fir	7.06	7	4.43	7	2.63	9	56
Tanbark Oak	4.94	5	4.89	7	.05	....	21
Spruce	.78	1	.57	....	.21	1	29
Total	95.98	100	66.84	100	29.14	100	....
VANCE'S.							
Redwood	25.44	40	5.94	17	19.50	68	105
Hemlock	23.25	37	19.50	56	3.75	13	32
White Fir	14.87	23	9.31	27	5.56	19	35
Total	63.56	100	34.75	100	28.81	100	....
RYAN'S SLOUGH.							
Redwood	52.24	66	24.43	79	27.81	57	81
White Fir	13.47	17	3.14	10	10.33	21	38
Red Fir	10.86	13	.76	3	10.10	21	41
Hemlock	2.95	4	2.57	8	.38	1	34
Total	79.52	100	30.90	100	48.62	100	....
SCOTIA AND DYERVILLE.							
Redwood	46.59	72	14.76	55	31.83	85	63
Tanbark Oak	8.59	14	7.90	29	.69	2	26
White Fir	7.93	12	4.29	16	3.64	10	31
Red Fir	1.41	2	.10	....	1.31	3	42
Total	64.52	100	27.05	100	37.47	100	....
FORT BRAGG.							
Redwood	38.21	64	13.02	60	25.19	67	79
Red Fir	8.16	14	1.04	5	7.12	19	39
Tanbark Oak	6.22	10	4.87	22	1.35	4	26
White Fir	4.56	8	1.60	7	2.96	8	33
Hemlock	2.11	4	1.42	6	.69	2	25
Total	59.26	100	21.95	100	37.31	100	....

The slope of the ground and the uneven height and density of the different species in mixture admit enough light to make the Redwood Slope comparatively open, so that, except where fires are frequent, there is a dense undergrowth of huckleberry, salal, Oregon grape, thimbleberry, and ferns.

Differences in altitude and the steepness of the slope cause differences in the condition of the forest. The higher the altitude and the steeper the slope, the sparser and poorer the growth becomes.

THE REDWOOD FLAT.

As the slopes become moderate, the altitude lower, the soil deeper, and the water supply better, the Redwood steadily gains on the other species and the forest becomes denser, until, on the rich flats and gulches, a second type is evolved. This is the Redwood Flat (Pl. II), and in its extreme form it has no other tree than Redwood.

The surveys for the following tables were taken on level ground, where the soil was deep and the moisture abundant.

TABLE 2.—*Redwood Flat.*

Locality and species.	Trees 4 inches and over in diameter breasthigh.		Trees 4 to 19 inches in diameter breasthigh.		Trees 20 inches and over in diameter breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breasthigh.
CRESCENT CITY.							*Inches.*
Redwood	37.10	63	12.79	42	24.31	85	84
Hemlock	19.16	32	16.02	52	3.14	11	28
Spruce	3.02	5	1.93	6	1.09	4	31
Total	59.28	100	30.74	100	28.54	100	....
SCOTIA AND DYERVILLE.							
Redwood	50.50	....	14.31	....	36.20	....	76

The Eel River stands are the extreme form of the Redwood Flat, and the tree here attains its greatest known height and clear length. On the benches that line the stream the Redwood possesses all the growing space, and casts a shade so dense that no ground cover except oxalis and occasional tufts of sword fern will grow beneath it.

While the heaviest stands and the best timber are found on the Redwood Flat, this type comprises a very small percentage of the Redwood forest, being confined mainly to narrow strips along the streams, occasional coastal plains, and the river deltas. The "rough country," as the Redwood slopes are called, so far exceeds the Redwood flats in extent that the proportion of the former to the latter is about 50 to 1.

CHARACTERISTICS OF THE REDWOOD

HEIGHT AND DIAMETER.

The Redwood grows to a greater height than any other American tree, but in girth and in age it is exceeded by the Big Tree of the Sierras. On the slopes 225 feet is about its maximum height and 10 feet its greatest diameter, while on the flats, under better conditions, it grows to be 350 feet high, with a diameter of 20 feet.

AGE OF THE REDWOOD.

Most of the Redwoods cut are from 400 to 800 years old. After the tree has passed the age of 500 years it usually begins to die down from the top and to fall off in growth. The oldest Redwood found during this investigation began life 1,373 years ago.

FORM AND DEVELOPMENT.

The tree, when normal, has a straight, slightly tapered bole, clear for more than a hundred feet, and a crown of horizontal branches that may occupy from a third to a half of its total length. (Pl. III, fig. 1.) Although without a taproot, it is well adapted to securing water in dry ground. The roots strike downward at a sharp angle, and are so large and so numerous as to form a compact mass of wood, in shape like an inverted funnel. The bark of the tree offers such a remarkable resistance to fire that except under great heat it is not combustible. It is of a reddish-gray color, fibrous in texture, and gives to full-grown Redwoods a fluted appearance.

The Redwood assumes a wide variety of shapes, and the normal is not its common form. In the old forests the crown may consist of a few long, flat limbs or of a mass of little bushy branches reaching from the ground to the top of the tree. (Pl. III, fig. 2.) Many Redwoods grow burls on the trunk that are 10 feet long, and some carry curious protuberances called "hanging necks," which droop and are open at the ends. Most of these irregularities in the tree are caused by the healing of its hurts. A windfall may break off the crown; immediately the broken limbs sprout and replace a part of what was lost. The fireproof sheathing of bark may be scraped away in a place and a little of the sapwood burned; the spot grows over and a burl may result. Fire may burn one of the branches and leave a charred snag behind; sapwood grows over the snag and forms a hanging neck. However badly the tree may be injured, if enough live wood is left it will heal the injury.

SOIL MOISTURE THE FIRST REQUISITE.

The Redwood requires little of the soil except that it be moist. The prevailing formation from Port St. George to Mendocino County,

where the tree grows, is a sandstone, complicated at different places with a later stratum, and the soil has a clayey to sandy consistency, greasy when wet, yellowish in color, and with a capacity for holding much water. Moisture available for the roots is the first need of the Redwood, as any hilly tract of forest will show. Wherever a small gully, or bench, or basin is so placed as to receive an uncommon amount of seepage, or wherever a creek flows by, there the trees are sure to be largest. Even if the soil be not rich, but merely gravel, and it contain much moisture, the Redwood will grow more abundantly there than on richer but drier ground.

THE REDWOOD FOLLOWS THE FOGS.

While moisture of the soil affects the development of the Redwood, moisture of the atmosphere regulates its distribution. The limits of the sea fogs are just about the limits of the tree. The fogs, unless scattered by the winds, flow inward among the mountains. Western exposures receive most of the mist they carry, except those higher ridges above their reach, which support, in consequence, only a scattering growth of Redwood. Eastern and southern slopes, where the sun is hot and the mists strike only occasionally, show few Redwoods, and these are short and limby.

THE QUALITY OF THE WOOD VARIES.

The wood of the Redwood varies greatly. The softest and best trees usually grow in the bottoms; the "flinty" timber occurs on the slopes. But this rule does not always hold good. Such fine tracts as those on the Crescent City flats show all sorts of unexpected and unaccountable differences in the quality of the timber. A soft, fine-grained tree will be found close beside one "flinty" and less valuable. Even the practical logger is never sure until he cuts it what kind of lumber a Redwood will yield. The tree's vitality is so great, it endures so may vicissitudes, and suffers from so many accidents in the centuries of its existence, that the grain of its wood becomes uneven in proportion as its life has been eventful. Most Redwoods become windshaken, or, if they escape this, the wood fibers formed under different rates of growth sometimes set up a tension so great that when the log is sawed the wood splits with a loud report.

THE LARGE REDWOODS OUTNUMBER THE SMALL ONES.

The Redwood forest is of the selection type; that is, it contains trees of widely varying ages in a single mixture, and keeps itself stocked by reproduction under its own shade. But while in the usual selection forest of other species the young trees far outnumber the mature ones, in a virgin Redwood forest as much as 72 per cent of the trees have been found to be above 20 inches in diameter.

REPRODUCTION BY SUCKERS AND BY SEEDLINGS.

Careful examination has proved that sucker and seedling share in the reproduction of the Redwood forest; but they share unequally, for the proportion of suckers to seedlings is as 100 to 1. The limited number of seedlings is due both to the quality of the seed and to the opportunities for germination afforded it. The habit of perpetuating itself by sprouts seems to have weakened the vitality of the Redwood's seed. Mr. P. Rock, of the horticultural staff at Golden Gate Park, says that under the best conditions only 15 to 25 per cent of Redwood seed will germinate. The seed requires more light than the forest usually affords it, and suckers cast so dense a shade as to crowd it out even when it does germinate.

Plates IV and V show how quickly Redwood will reproduce itself from sprouts. In Pl. IV, fig. 1, is represented the growth of the first few months after the slashing was logged and burned. Such shoots are as soft and juicy as asparagus. In Pl. IV, fig. 2, is seen the size and development reached in six to eight years. In Pl. V, fig. 1, are shown suckers which have passed the age of twenty-five years, and which have begun to take on a forest form. The parent stump is visible in the rear. Pl. V, fig. 2, shows a characteristic clump of mature Redwoods, surrounding and concealing the parent stem, but revealing unmistakably their identity as sprouts.

YIELD OF REDWOOD STANDS.

The yield of virgin Redwoods on the northern flats is from 125,000 to 150,000 board feet per acre. Farther south it is much less. About Humboldt Bay it is from 50,000 to 75,000 feet per acre; and on slopes like those in Sonoma County, from 20,000 to 30,000 feet. The amount of timber got out of a Redwood forest is only a small proportion of what the stand contained. At least a quarter of the timber is destroyed in felling and in the burning that follows, and of what remains all the broken and misshapen logs are left on the ground.

TOLERANCE, OR SHADE-ENDURING QUALITIES.

The seed of the Redwood will not germinate in shaded places; the small seedling demands plenty of light. The crown is almost as thin and open as that of the larch—another sign that the tree is not naturally shade-enduring. In a mixed stand the Redwood's branches die off more rapidly than those of its companions, and the crown bends eagerly to the places where the light enters the forest canopy. But in spite of these signs of its sensitiveness to light, the Redwood forms one of the densest forests that grow.

The reason for this is that the stand is chiefly maintained by suckering from old trees. Supported and nourished by full-grown roots and stems, young trees grow under shade that would kill the small seedling.

The sprout manages to survive year after year by connection with its parent, and to make a slight increment of wood. When an old tree is felled, more light is let in, more nourishment made available, and the sprout shoots up with all its native vigor.

The sprout will endure an astonishing amount of shade. In stands of second growth, so dense that not a ray of sunlight can enter, saplings 6 or 8 feet high are to be found growing from stumps, bare of branch or foliage except for a few inches of pale green crown at the top. In very dark, damp places in the virgin forest one may find clumps of shoots as white as sprouts from a potato in a cellar.

The tolerance of the Redwood sprout depends somewhat on soil moisture. On the bottoms the tree is enabled to stand so much shade that other species are usually driven out of competition for the ground. On the hills, where there is less moisture and more light, the Redwood generally gives way to the less tolerant Fir and to such drought-enduring species as Tanbark Oak and Madroña.

ENEMIES OF THE REDWOOD FOREST.

The enemies of the Redwood are few, and it suffers from them less than other trees. The wind can scarcely uproot it, insects seem to do it little harm, and fungi seldom affect it. Even fire, the great enemy of all trees, though it may occasionally kill whole stands of young Redwood growth, is unable to penetrate the fireproof sheathing of shaggy bark with which the old trees protect themselves.

FIRE.

For centuries fires have run through Redwood forests. They have killed young growth, made "goose pens" by burning out the litter from between the roots, and scarred the bark of the older trees; but the Redwood has suffered less from fires than has any other species. In the damp northern part of the Redwood belt the forest is too wet to burn. Farther south, during August and September, while the trade winds are blowing and the land is dry from lack of rain, fires are frequent. Even then, unless the conditions are exceptional, the fires are seldom dangerous. But if the dry season has been unusually long and the wind is very high, and a fire is driven down from the bald hills into the heavy timber of the flats and gulches, the flames may gain such headway as to sweep from the forest all the younger trees and the underbrush. Ridge fires commonly clear the ground of underbrush and occasionally kill small trees. In September, 1900, a ridge fire occurred near Occidental, Sonoma County, where the forest of Redwood, Fir, and Tanbark Oak is thin and scattering, with dense, dry underbrush. The wind drove the flames over the ground as fast as a man could run; fences, bridges, and farm buildings were burned; young timber was killed and the growth of the old timber checked.

Complete recovery from such a fire is slow. The leaf mold is burned off and the soil is made naked as a road. The large Redwoods will sprout again from their stumps; but the rest of the space, once occupied by Fir and Oak, will be covered first by buck brush and blue blossom, until, after years, the Fir and Oak return.

The common cause of fire in the forest is the carelessness of campers and settlers, who leave their camp fires burning. Sparks from the brush fires of logging camps occasionally start a blaze in the timber, and lightning may be responsible for a few forest fires.

WIND SELDOM UPROOTS THE REDWOOD.

When a strong wind follows a long rainy season, Redwoods exposed on high ridges may sometimes be blown down, but no considerable tracts of forest are ever overthrown.

SPECIES IN MIXTURE.

Of the trees which grow with the Redwood in the forest the following are the most important:

Red Fir, *Pseudotsuga taxifolia* (Lam.) Britt.
Tanbark Oak, *Quercus densiflora* Hook. & Arn.
Sitka Spruce, *Picea sitchensis* (Bong.) Trautv. & Mayer.
Port Orford Cedar, *Chamaecyparis lawsoniana* (Murr.) Parl.
Giant Arborvitae, "Red Cedar," *Thuja plicata* Don.
Western Hemlock, *Tsuga heterophylla* (Raf.) Sargent.
Lowland Fir, "White Fir," *Abies grandis* Lindl.
Pacific Yew, *Taxus brevifolia* Nutt.
California Torreya, *Tumion californicum* (Torr.) Greene.
Knobcone Pine, *Pinus contorta* Loud.
California Laurel, "Pepperwood," *Umbellularia californica* (Hook. & Arn.) Nutt.
Madroña, *Arbutus menziesii* Pursh.
Cascara Buckthorn, "Cascara Sagrada," *Rhamnus purshiana* de C.
Red Alder, *Alnus oregona* Nutt.
Gowen Cypress, *Cupressus goveniana* Gord.

These trees are usually beaten in the struggle for growing space by the Redwood, which is climatically the most favored, but each species finds places here and there where the conditions enable it to hold its own. Red Fir, or Oregon Pine, the most abundant and important of the trees in mixture, occurs with Redwood everywhere except on damp flats and in gulches. It grows best on medium soil, on ridges and high flats where the forest is comparatively open. On some fine tracts, as in Del Norte County, it constitutes 75 per cent of the stand. Next to Redwood, it is the most used of the timber trees on the coast, and in Mendocino County forms from 10 to 20 per cent of the output of the mills.

FIG. 1.—SPROUTS 25 YEARS OLD, CRESCENT CITY.

FIG. 2.—MATURE SPROUTS IN VIRGIN TIMBER, CRESCENT CITY.

REDWOOD LOGGING. "FALLERS" MAKING THE UNDERCUT, CASPAR, MENDOCINO COUNTY, CAL.

REDWOOD LOGGING. THE YARDING DONKEY AND YARDING CREW, CASPAR, MENDOCINO COUNTY, CAL.

Fig. 1.—Logged Slope on Big River.

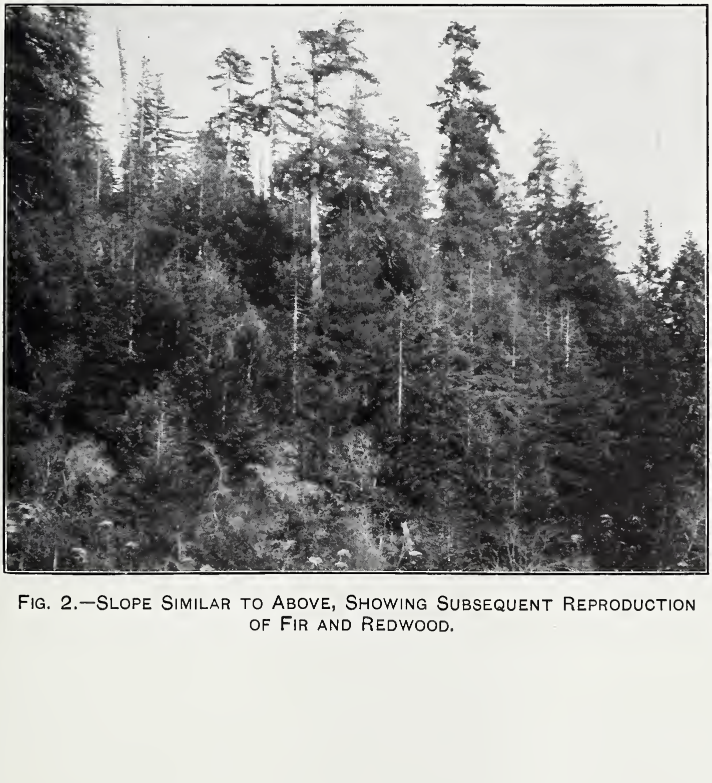

Fig. 2.—Slope Similar to Above, Showing Subsequent Reproduction of Fir and Redwood.

LUMBERING: ITS HISTORY AND EXTENT.

The Spaniards, near San Francisco Bay, were the first to log the Redwood forests, but their cuttings were very small. Late in the eighteenth century a Russian colony cleared a tract of Redwood, which has since grown up to good timber and again been cut over; but no considerable amount of logging was done until long after the Russians had left. About the year 1850 small mills started up in Santa Clara and Santa Cruz counties, at Albion, and at the mouth of Big River, in Mendocino County, at Arcata and Eureka, on Humboldt Bay, and at Trinidad. At first the mills on Humboldt Bay cut chiefly Red Fir and Sitka Spruce, as Redwood was not valued; and the other mills cut very little Redwood, since the tree was without a market and the mill men were handicapped by the lack of improved machinery. In those days logs were usually driven to the mill in the rivers, and the strong freshets carried many out to sea. As soon as the growth of San Francisco and the settlement of the southern counties developed a market, more companies and better methods came in. Logging railroads superseded driving, and donkey engines did the work of teams. By the early nineties mills were employing about the same number of men as now (1900) and had about their present equipment.

PRESENT OPERATIONS.

Redwood lumbering is now narrowed to northern counties in California. In Santa Cruz County all the large stands of Redwood will be made into a park. In Marin County Redwood has long since dwindled to a few isolated groves, used mostly as picnic grounds. In Sonoma County Redwood holdings are reduced to a few scattered claims. Large operations begin in Mendocino County. The ten sawmills in this county had in 1900 cleared 150,000 acres, or 25 per cent of the total acreage, including the largest and best stands. In Humboldt County the mills had cleared 65,000 acres, and in Del Norte County two mills had cleared 3,000 acres. It is unsafe to estimate what proportion of the original stand these cuttings represent.

QUALITIES OF THE WOOD.

Redwood possesses qualities which fit it for many uses. In color it shades from light cherry to dark mahogany; its grain is usually straight, fine, and even; its weight is light; its consistency firm, yet soft. It is easily worked, takes a beautiful polish, and is the most durable of the coniferous woods of California. It resists decay so well that trees which have lain five hundred years in the forest have been sent to the mill and sawed into lumber.

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RESISTANCE OF LUMBER TO FIRES AND INSECTS.

The wood is without resin and offers a strong resistance to fire, as is indicated by the record of fires in San Francisco, where it is much used. Insects seldom injure it, because of an acid element its lumber contains. In sea water, however, the marine teredo eats off Redwood piling as readily as other timber.

USES FOR REDWOOD.

Redwood is used for all kinds of finishing and construction lumber, for shingles, railroad ties, electric-light poles, paving blocks, tanks, and pipe staves. It is an excellent wood for all these purposes. As a tie its average life, under heavy traffic, is six to eight years; as shingles it will last as long as forty years. The chief difficulty in working Redwood lies in the seasoning process. The tree absorbs so much moisture that the butt logs will sink in water. Left in the sun, they require three or four years to dry.

COST OF LUMBERING.

The manufacture of Redwood lumber is costly and difficult. From the felling of the tree to the delivery of the finished product unusual problems and expenses beset the mill man. Most of the land where the Redwood grows is rough and hilly, and from 100 to 250 miles from the main market, which can be reached only by sea. None but the big companies can operate with any profit, and each plant has usually to own a complete outfit. This includes the mill and accompanying buildings, about 10 miles of railroad track, two locomotives, three to six donkey engines, several logging camps (including all the rigging and tools that go with them), and perhaps a pair of steam schooners. The men employed number from 150 to 300. Yet, even on such a scale, the business is very uncertain. On account of the sparseness of the settlement, labor is scarce and high and taxes are severe. The most prosperous companies are those which have developed a town with their business. They run a general store, raise most of their own supplies, and sometimes have a local sale for their common lumber and for firewood.

Redwood lumber is at present not highly profitable to mill men. It costs, according to the accessibility of the timber and the price of labor, from \$3 to \$5.50 a thousand feet, board measure, to log—that is, to deliver at the mill; from \$3 to \$3.50 to saw; from 25 to 50 cents to load, and from \$2.50 to \$4 to ship to the city. These items, with the expenses of the city offices and sales, bring up the average total to \$10.75, or in many cases, with insurance, taxes, interest on capital, stumpage, and accidents reckoned in, about \$12.

WHERE THE LUMBER GOES.

The market is uncertain and limited. Redwood must depend for its sale on the demand of San Francisco, Los Angeles, and the southern counties of the State. Occasional cargoes go to Australia, Honolulu, South America, and the Orient; but this outlet is restricted by the necessity for costly reshipment at San Francisco, since seagoing vessels can not load everywhere on the coast. For five years prices have remained $11 to $13 for rough, and $18 to $25 for clear, merchantable Redwood. This leaves little room for profit. It would appear that so useful a wood should find a ready sale in the East; but at present Eastern buyers do not appreciate its good qualities, and high freight rates have helped to keep it out of Eastern markets.

DESTRUCTIVE LUMBERING METHODS.

Redwood lumbering is expensive and difficult. Steam is used throughout the process. On the flats and bottoms, where the trees average from 5 to 15 feet in diameter, the stand is very dense, and to get Redwood out of the forest without breaking other trees is not an easy task. Choppers who can save a good percentage of the wood in the trees felled must be experienced men. If the tree is not felled so as to strike throughout most of its length at the same time, the brittle wood will break and splinter badly. To prevent this, a "lay-out" is usually leveled for the tree to fall on. Even then the whole of the crown and at least a fourth of the bole are demolished and strewn upon the ground. The mass of broken branches may lie shoulder deep, and the logs must be got out from this tangled wreckage.

After the choppers have done their work, the "ringers" and "peelers" follow. They peel the bark from the logs and let it lie with the broken branches, which soon dry and are then set afire. When bark and branches are consumed the logs lie free, and the logger can put sawyers and swampers to work, and move in his yarding donkey engine and rigging. Many small trees used by the yarding crew to set blocks are unavoidably girdled; the rest are in constant danger from the moving logs, which work this way and that, plow into the earth, and butt into the young trees until scarcely one of them is left unharmed.

After the yarding crew has done its work the log's progress to mill is over land already slashed and burned. Three or four logs are coupled together, attached to an endless cable, and hauled to the railroad track by a bull-donkey engine, which stands on a landing at the end of the skid road and winds in a wire rope on a drum. Then, with block and tackle, worked either by the train locomotive or a smaller donkey engine, the logs are loaded upon trucks and hauled to the mill pond. (Pls. VI and VII.)

CUT-OVER LANDS: POSSIBILITY OF SECOND GROWTH.

During the fifty years in which the Redwood has been lumbered, several hundred thousand acres of timber have been cut over. The good lands have been put into cultivation under fruit or grain, or, where mills have had a large and permanent force of men to feed, the mill owners have turned their cut-over lands into pasture for the raising of cattle.

The chance for the reproduction of the tree has been small. On the farms the stumps are either grubbed out or shorn of their suckers every year; on pasture lands, burning and the cattle have prevented reproduction; and those lands not used after lumbering have also been subjected to fire. As year by year the Redwood forests have dwindled, it has come to be pretty generally believed that the tree is doomed to extinction.

The popular idea that the Redwood has no chance of survival is not well founded; the possibilities of second growth are much better than they appear. While most of the lumbered areas have been kept bare by lack of protection, there are tracts where accidentally favorable conditions have allowed the sprouts to develop, and here the real vigor of the Redwood second growth is apparent.

VALUABLE SECOND GROWTH.

On the northernmost slashings near Crescent City, which is perhaps the most isolated of all the lumber regions on the coast, there is one small tract among acres of unpromising brush and stumps where the growth of sprouts has been unimpeded, and there a stand exists which averages 12 to 16 inches on the stump and is 60 to 80 feet in height. Only the very best of the virgin timber may be profitably lumbered in this place, and the second growth is not cut. A hundred miles south, near Humboldt Bay and Eureka, are tracts of young growth only ten years older than those at Crescent City, which have a market value. Men who have found their old claims grown up to sticks 20 inches through and a hundred feet long have sold the trees for piling, for which they are locally considered almost as good as Red Fir. A good many mill men in Eureka believe that the Redwood sucker will in time and under the proper conditions produce valuable timber; but they say that the wood of the sprout is too soft and brittle—"brashy" they call it—not taking into account that it has not been grown in dense stands and has not had time to harden.

This soft timber can be used. In Sonoma County, where the country is well settled, Redwood was never so dense as farther north; but there has been a better chance for reproduction and there is a better market. Sonoma County second-growth Redwood is cut to as low a diameter as 10 inches, and the mills are making money at the business. The timber is sappy, but it makes good box boards and good lumber.

This contrast between the indifference with which second-growth Redwood of large size is regarded in Crescent City and the readiness with which much smaller stuff is used in Sonoma County, where there is a market for it, is significant. It is one of the signs which go to show that second growth has a future, and that better times for the Redwood are near at hand.

A BETTER MARKET NECESSARY.

The important matter is that the market should improve; and the market is improving. The northern country is opening up; railroads are entering where the large trees grow, and buyers are learning more about the good qualities of the Redwood lumber. All this makes it the more worth while to the lumberman to plan for a second crop on his Redwood lands.

A STUDY OF SECOND-GROWTH REDWOOD.

To learn the rate of growth of second-growth Redwood a study was made of some of the largest of such stands. The investigation began with the timber near Crescent City. In that place logging operations have so far been confined to the coastal plains between the sea and Smith River, a plain once forested with a heavy growth of Redwood, Spruce, and Hemlock.

THE TRACT AT CRESCENT CITY.

The second growth studied near Crescent City was on the crest of a small rise, just above sea level, where the original stand of timber was cut off in 1873–1875. The trees covered 6 acres; they had suffered no burning since the first crop was logged, and there had been no other interference with the reproduction. The age of the stand was 25 to 30 years.

TRACTS AT EUREKA AND ARCATA.

Two small tracts were studied near Eureka and Arcata. They were on good soil, 200 to 300 feet above sea level, on rolling ground. At Eureka 20 per cent of the forest was Red Fir; at Arcata 15 per cent was Red Fir and White Fir. The Eureka stand was 35 years old; that at Arcata, 40 to 45 years.

THE REDWOOD'S FIGHT FOR THE GROUND.

The stands at Crescent City, Eureka, and Arcata represent the best conditions for the growth of suckers. When the old Redwood is cut the stumps sprout abundantly; a few Spruces and Hemlocks seed up the gaps; and these three species, with the help of small shrubs, soon form a dense thicket. In a few years the Spruce and Redwood and other fast-growing trees, like Alder, begin to overtop and shade out the brush and small plants; the dead vegetation deposits a leaf muck,

or humus, which enriches the soil, keeps it moist, and makes growth more rapid. As the crowns grow up, in the struggle for light and room most of the weak or intolerant trees die off. The Hemlocks survive and partly keep up, because they can stand a good deal of shade, but the Willows and Alders become restricted to the openings. It happens, therefore, that wherever the suckering has been thick enough at first, Redwood finally dominates all the other species and occupies most of the ground.

THE TRACT AT TRINIDAD.

A fourth tract, which showed more typical conditions and the kind of situation characteristic of most of the Redwood belt, was found at Trinidad. The topography there is a broad coastal terrace, rising gently from the sea cliffs and cut by the canyons of several small streams. About 2 miles inland the terrace rises to an altitude of 500 feet, and the soil becomes coarse and poor. The tract of second-growth Redwood stands on a plateau-like divide between the two gulches. The age of the stand is 25 years.

THE VALUATION SURVEYS.

Valuation surveys were run at Crescent City, Arcata, and Trinidad. The results are given in the following table:

TABLE 3.—*Valuation survey of second-growth Redwood.*

Locality and species.	Trees 2 inches and over in diameter, breasthigh.		Trees 2 to 13 inches in diameter, breasthigh.		Trees 14 inches and over in diameter, breasthigh.		
	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average number of trees per acre.	Percentage of each species.	Average diameter breast-high.
ARCATA.							*Inches.*
Redwood	192.10	80	162.70	79	29.40	84	17
White Fir	34.10	14	30.30	15	3.80	11	15
Spruce	11	5	10.20	5	.80	2	14
Red Fir	3.30	1	2.30	1	1	3	17
Total	240.50	100	205.50	100	35	100	....
CRESCENT CITY.							
Redwood	234.33	55	204	53	30.33	75	16
Spruce	104.33	25	99.66	26	4.67	12	17
Hemlock	86	20	80.67	21	5.33	13	17
Total	424.66	100	384.33	100	40.33	100	....
TRINIDAD							
Redwood	401.6	66	399.20	75	2.40	12	14
Red Fir	134.4	22	120.40	23	14	70	15
Hemlock	62	10	....	....	....	....	....
Spruce	7.6	1	7.20	1	.40	2	14
Pine	5.6	1	2.40	1	3.20	16	15
Total	611.2	100	529.20	100	20	100	....

HOW THE TABLES WERE MADE.

In the tables which follow, trees 14 inches and over in diameter are assumed to be merchantable. This is done because a 14-inch tree is the smallest that will contain a log which is salable by the Spaulding Rule, and because it is the smallest tree used by the mills.

The volume tables are based on stem analyses, obtained by measuring 450 trees at Crescent City, 50 at Eureka, and 50 at Arcata.

To find the volume per tree in board measure, all the trees analyzed, beginning with those that contained a log 12 feet long and 10 inches in diameter at the small end inside the bark, were scaled, and the results for each diameter plotted in a curve. The table of merchantable volume given here was derived from the curve. It gives the average volume in board feet and the height of each tree for diameters from 14 to 27 inches, inclusive.

TABLE 4.—*Merchantable volume of Redwood timber.*

Diameter breast-high.	Merchantable volume.	Total height.	Diameter breast-high.	Merchantable volume.	Total height.
Inches.	*Board feet.*	*Feet.*	*Inches.*	*Board feet.*	*Feet.*
14	52	69	21	186	88
15	62	72	22	188	91
16	74	75	23	226	93
17	90	78	24	267	95
18	108	81	25	316	97
19	130	83	26	430	99
20	156	86	27	496	101

The yield per acre of merchantable timber at Crescent City and Arcata is given in the following table (No. 5). The figures were found by multiplying the number of trees per acre in each diameter class, as found in the valuation survey tables, by the figure corresponding to that diameter class in the table of merchantable volume. Only Crescent City, Eureka, and Arcata showed trees large enough to be scaled on the standard chosen. At Eureka the culling of the forest for piling had left nothing on which to base an estimate of yield per acre.

TABLE 5.—*Merchantable yield of Redwood per acre.*

Diameter breast-high.	Crescent City.		Arcata.	
	Average number of trees per acre.	Merchantable yield.	Average number of trees per acre.	Merchantable yield.
Inches.		*Board feet.*		*Board feet.*
14	17.7	920.4	13.5	702.0
16	6.0	444.0	7.0	518.0
18	2.7	291.6	4.4	475.2
20	1.5	234.0	2.0	312.0
22	1.0	188.0	1.1	206.8
24	1.0	267.0	.5	133.5
26	.3	129.0	.2	86.0
Total		2,474.0		2,433.5

Table 6 shows the number of pile feet in trees of diameters from 18 to 28 inches, inclusive. It was obtained from stem analyses taken at Crescent City, Arcata, and Eureka. Assuming that nothing which will not furnish a log 30 feet long and 10 inches in diameter at the small end is available for piling, the smallest tree to contain a pile was found to be 18 inches in diameter breasthigh. The table follows:

TABLE 6.—*Pile length of Redwood.*

Diameter breast-high.	Pile length.	Diameter breast-high.	Pile length.
Inches.	*Feet.*	*Inches.*	*Feet.*
18	30.5	24	49.0
19	33.5	25	52.0
20	37.0	26	54.5
21	40.0	27	57.5
22	43.0	28	60.0
23	46.0		

Diagrams 1 and 2 show the relations between age and height, and between age and diameter, of the Redwood examined at Crescent City, Eureka, and Trinidad.

FIG. 1.—SECOND-GROWTH REDWOOD AT EUREKA, 30 TO 35 YEARS OLD.

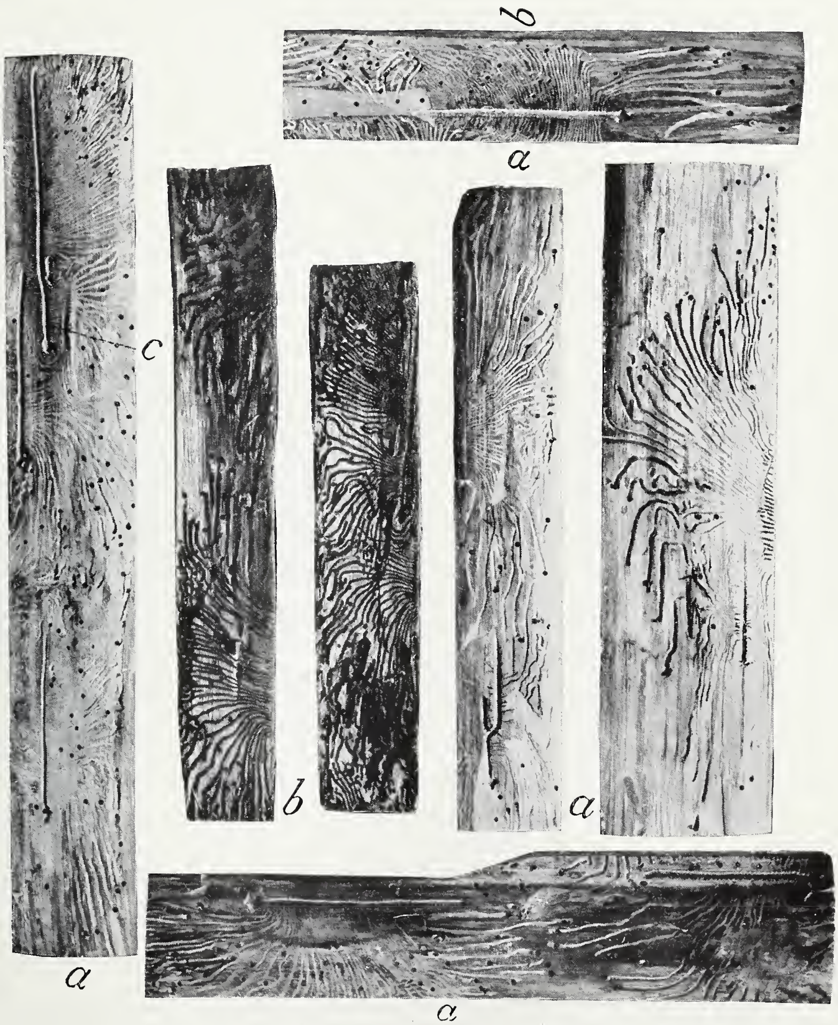
FIG. 2.—SECOND-GROWTH REDWOOD AT MENDOCINO, 40 TO 45 YEARS OLD.

FIG. 1.—DISTRIBUTION OF POCKETS OF DISEASED WOOD.

FIG. 2.—POCKETS OF DISEASED WOOD IN VARIOUS STAGES.

SECTIONS OF REDWOOD LOGS, SHOWING BROWN ROT.

TANGENTIAL SECTION OF REDWOOD LOG AFFECTED WITH BROWN ROT.



WORK OF THE REDWOOD BARK-BEETLE.

a, Surface of wood grooved by primary galleries and larval mines; *b*, bark with galleries and mines through inner layer; *c*, primary or egg gallery (original).

DIAGRAM No. 1.

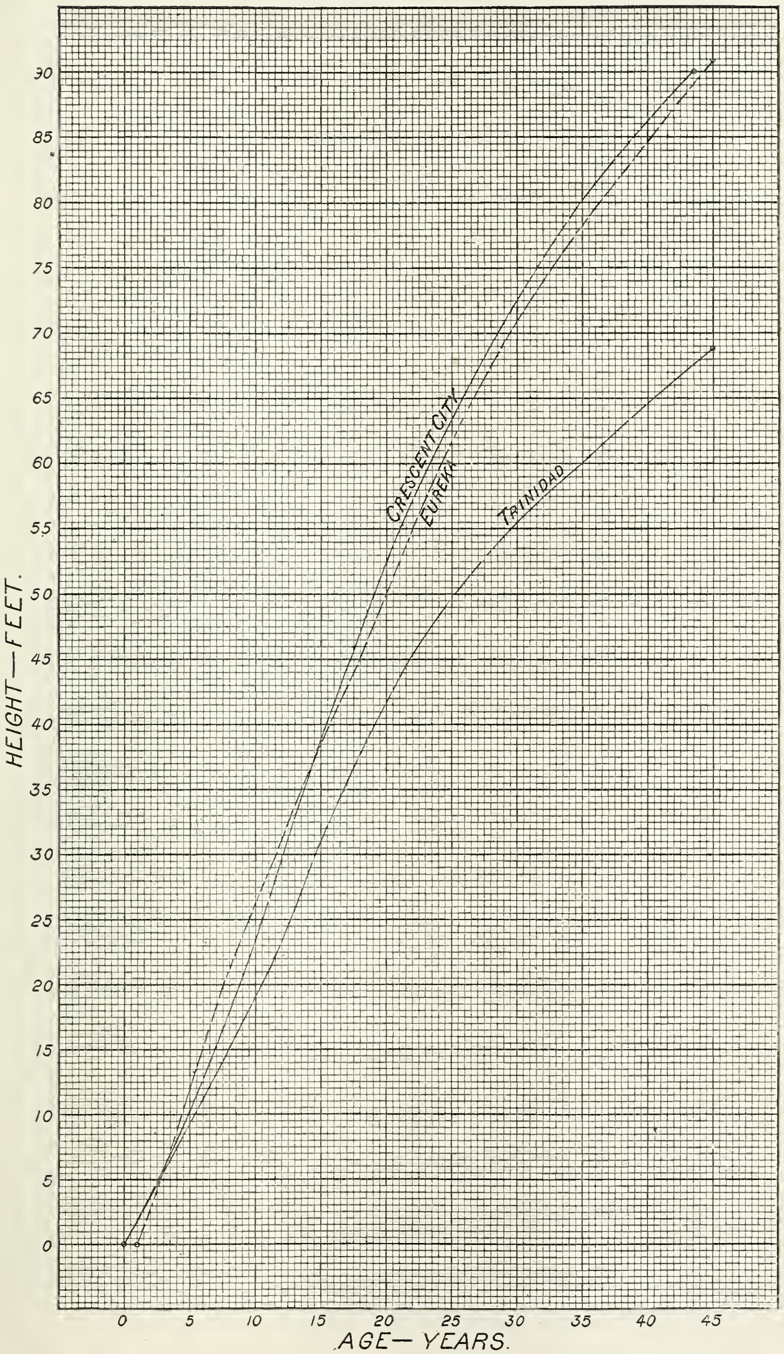

CRESCENT CITY
EUREKA
TRINIDAD
HEIGHT—FEET.
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
AGE—YEARS.
0
5
10
15
20
25
30
35
40
45

DIAGRAM No 2.

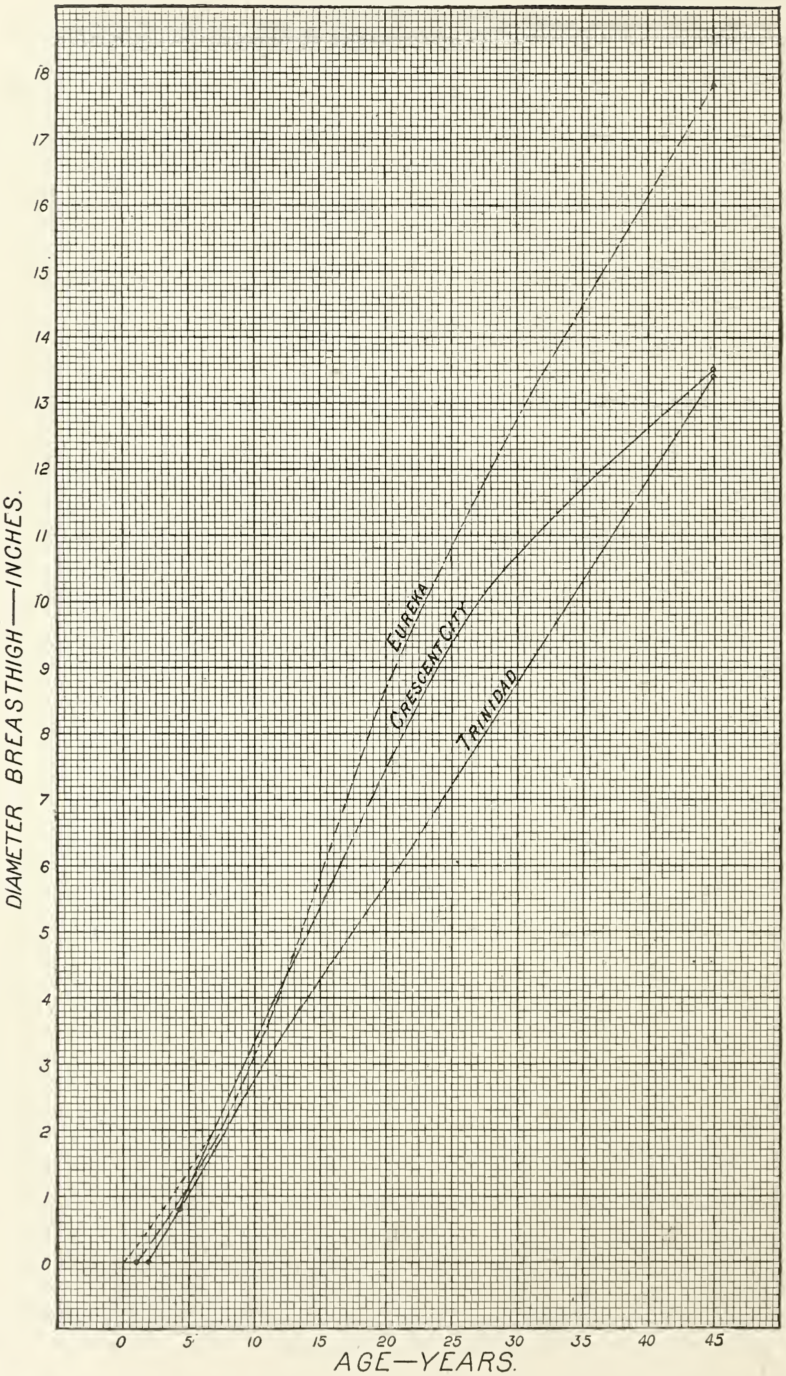

DIAMETER BREASTHIGH—INCHES.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
5
10
15
20
25
30
35
40
45
AGE—YEARS.
EUREKA
CRESCENT CITY
TRINIDAD

Table 7 shows the relation between sapwood and heartwood for diameters of from 4 to 22 inches, inclusive. The amount of sapwood varies both with the diameter and the age. This table was constructed from measurements of trees taken at Crescent City, Eureka, and Arcata, which were used in the volume table, and of 400 trees at Trinidad too small to be used in the volume table.

TABLE 7.—*Width of sapwood and diameter of heartwood.*

Diameter breast-high.	Eureka.		Arcata.		Crescent City.		Trinidad.	
	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.	Width of sapwood.	Diameter of heart-wood.
Inches.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
4	1.70	0.6	1.50	1.0	1.65	0.7	1.55	0.9
5	1.90	1.2	1.60	1.8	1.70	1.6	1.70	1.6
6	2.05	1.9	1.70	2.6	1.80	2.4	1.75	2.5
7	2.10	2.8	1.80	3.4	1.90	3.2	1.80	3.4
8	2.20	3.6	1.90	4.2	2.00	4.0	1.85	4.3
9	2.25	4.5	1.90	5.2	2.10	4.8	1.90	5.2
10	2.30	5.4	1.95	6.1	2.15	5.7	1.95	6.1
11	2.35	6.3	2.00	7.0	2.25	6.5	2.00	7.0
12	2.40	7.2	2.05	7.9	2.30	7.4	2.05	7.9
13	2.40	8.5	2.10	8.8	2.40	8.2	....	....
14	2.45	9.1	2.10	9.8	2.45	9.1	....	....
15	2.50	10.0	2.10	10.8	2.50	10.0	....	....
16	2.55	10.9	2.15	11.7	2.60	10.8	....	....
17	2.60	11.8	2.15	12.7	2.65	11.7	....	....
18	2.65	12.7	2.20	13.6	2.70	12.6	....	....
19	2.70	13.6	2.20	14.6	2.80	13.4	....	....
20	2.80	14.4	2.20	15.6	2.85	14.3	....	....
21	2.90	15.3	....	....	....	....	....	....
22	3.00	16.0	....	....	....	....	....	....

WHERE THE TABLES APPLY.

The tables given in this bulletin furnish the most accurate knowledge of the Redwood's growth now available. The Crescent City, Eureka, and Arcata figures are applicable to Redwood flats, where the ground is low and moist. The Trinidad tables may be applied to all that great body of Redwood of the slope type which occupies high lands and steep slopes.

CONCLUSIONS.

THE SIMPLEST MANAGEMENT THE BEST.

The narrow profits of Redwood lumbering prevent any but the simplest systems of forest management. Excellent results can, however, be accomplished by inexpensive methods.

WHAT ONE COMPANY HAS DONE.

An interesting case of conservative Redwood management is found in Mendocino County, where the Mendocino Lumber Company has

consistently logged with an eye to the future value of its holdings. The forest is the usual ridge-timber type of Redwood, Red Fir, and Tanbark Oak, varied with occasional bottom-land stands of pure Redwood; and the practice has been to cut no trees under 20 inches in diameter (Pl. VIII). The trees left standing have in a few years so restocked the ground with Redwood suckers and Fir seedlings that at a distance the hillsides look well wooded. In most places the stand is thick enough to insure clear trunks and render the danger from fire much less than it would have been under the usual system of laying bare the land.

The result has been in every way worth the effort. It cost next to nothing to make the experiment, for the trees left standing had no market value.

Instead of bare ridges washed by rain and run over by fires, there is now a young forest, which keeps the soil moist and firm and feeds the water into the streams so gradually as to cause an even flow. The land is becoming more and more valuable as the forest grows.

These advantages were gained at the trifling expense of using care to save the small trees in logging. On some areas, where the old stand was heavy, there is young Redwood only 45 years old that is 20 to 30 inches on the stump and nearly 100 feet high (Pl. IX, fig. 2). This timber is already marketable as piles. The whole area of the Mendocino Lumber Company will again bear timber and regain much of its former value.

The Mendocino Lumber Company's management of its Redwood is worthy of careful attention. The example it has set is especially to the point, because it shows a practical and cheap method of dealing with a difficult problem. At little expense and trouble the company has assured itself of future crops of timber, and has thereby considerably increased the selling price of its cut-over lands. The conditions under which these results were brought about were not exceptional, but average; they prevail throughout a greater part of the Redwood belt.

Something more than what the Mendocino Company has done may be necessary in some cases. For example, something might be spent in protecting the cut-over lands from fire until the young growth can protect itself. But whatever is done must be done with a sharp eye to the cost.

THE BROWN ROT DISEASE OF THE REDWOOD.

By Hermann von Schrenk,
Bureau of Plant Industry.

The Redwood is one of a group of trees of ancient lineage, all of which are singularly free from fungus diseases. A number of parasitic fungi, such as *Leptostroma sequoiæ* Cook & Harness., and *Stricta versicolor* Fr., attack the living leaves and branches; but they occur so rarely, and then only in such small numbers, that they are practically insignificant. Dr. Farlow states that "more than thirty species have been recorded on *Sequoia sempervirens*," none of which is known to cause serious disease. In Europe, where the Redwood has been grown for many years as an ornamental tree, a species of Botrytis frequently attacks the young branches.

Redwood timber possesses lasting qualities scarcely equaled by any other wood. Although very light and porous, it has antiseptic properties which prevent the growth of decay-producing fungi. So far as is now known, none of the ordinary wood-rotting fungi grow in Redwood timber. This is an exceedingly valuable property, which should extend the use of the wood for all kinds of construction purposes.

It is because of its resistance to most forms of decay that the Redwood reaches such a great age. A remarkable fact to be noted is that the innermost rings of most of the trees are as sound now as when first formed.

Only one disease of the trunk is now known, commonly called butt, brown, or pin rot. The wood at the base of the trunk of diseased trees is filled with many pockets of dark brown, almost black, wood, irregular in form, though usually twice as broad as they are long, and ranging in size from mere specks to masses several inches in diameter (Pl. XI). They may join at the ends very much as they do at the sides. At first the individual masses of diseased wood are separated from one another by lamellæ of sound wood, and the line of division is sharply defined (Pl. X, fig. 2). In later stages of the disease the dividing lamellæ are changed into brown wood, thereby causing two or more masses to unite (Pl. X, figs. 1 and 2). The bases of the older trunks affected by this disease may be masses of brown decayed wood.

The brown wood is very brittle and has all the properties of charcoal. Under a little pressure it will crumble into a fine powder. As the wood decays, it shrinks considerably. This reduction in volume causes large cracks to appear in the brown wood, and in some instances the diseased wood separates entirely from the sounder wood and lies loose in the pocket.

The decay starts in the inner rings of the heartwood and extends outward gradually until all the heartwood is pitted (Pl. X, figs. 1 and 2). Several instances have been found where small pockets had formed in the sapwood. The brown rot starts at the ground and extends from the roots upward into the trunk for distances varying from 3 to 50 feet, and in some cases probably higher. As a rule, though, it does not go farther than 10 to 15 feet in the butt, so that by cutting off a butt log of about that length sound wood can generally be reached. The brown rot is found in older trees only, so far as observed by the writer, and seems to develop very slowly.

At present no one fungus can be determined to be the cause of this disease. Under the best conditions it is a matter of great difficulty to ascertain the cause of a disease which affects the roots and butts of trees; but in the case of the Redwood the immense size of the tree and its thick bark and formidable buttresses render an accurate determination of the disease which affects it impossible without long study. There are many saprophytic fungi which grow on the dead bark and in and about the roots of the Redwoods, but in the present incomplete state of our knowledge it would be hazardous to connect any one of them with this disease.

Reference may be made to the close resemblance of the brown rot to the pin rot of *Libocedrus decurrens*. The diseased wood of the Incense Cedar is filled with brown pockets which closely resemble those of the Redwood. These pockets occur in the tops of the trees, however. The fungus causing this disease is *Polyporus libocedris*,[a] so far found only on Libocedrus. It may be that it causes the rot of the Redwood. The fact that the Redwood disease occurs in the base of the trees ought to furnish no objection to such an assumption, since there are other cases where the same fungus attacks one tree in the crown and another nearer the ground—*Trametes pini*, for instance, which causes the disease of most of the pines in the tops of the trees, attacks *Pinus monticola* very close to the ground.

The brown rot has so far been reported as rather prevalent in northern California. Near Fort Bragg and Crescent City the writer found it in a good many old trees. It probably occurs throughout the Red wood belt.

Brown rot is not so serious as to cause alarm; it does practically lit-

[a] von Schrenk, H. A disease of Taxodium known as Peckiness; also a similar disease of *Libocedrus decurrens*. Rep. Mo. Bot. Garden, 11:2, 3, 1900.

tle harm. The disease may possibly develop in timber that was partly decayed when cut from the tree, although in several cases observed such timber was used for posts or ties and did not deteriorate further. Where strength is not the first requirement, wood in the early stages of decay may be classed in a low grade for posts or ties.

Measures for preventing decay in Redwood are impracticable.

DECAY IN REDWOOD POLES.

As this bulletin goes to press the writer is in receipt of samples of decayed Redwood taken from telegraph poles in California that were set in 1877. They were 12 inches square at the butt and were set 5 feet into the ground. About half of them showed signs of decay this year; half of this number had decayed from the outside in, while the other half showed rot within the poles. Many poles that were broken off by a windstorm had been decayed to a depth of several inches.

The decay very closely resembles the red rot. The diseased wood is red-brown, brittle, and porous. In cases where the decay started on the outside, the spring wood cells were attacked first, leaving the summer cells practically intact. In the decayed wood many colorless hyphæ traverse the walls, and here and there are found groups of colored spores. No fruiting organs of any fungus occurred on the samples sent.

PREVENTION.

The decay of poles of the Redwood can probably be retarded considerably by thoroughly drying the poles before setting them. Careful inspection will often show, at the butt end, signs of the brown rot disease of the living tree. Poles from such trees should not be used. Dry poles can be coated with some preservative substance, which will probably retard decay considerably. Tests are now under way with the Redwood to determine the best method for preventing this rot.

EXPLANATION OF PLATES.

Plate X. Cross sections of Redwood logs (Fort Bragg, Cal.), showing brown-rot disease. Fig. 1 shows distribution of pockets. Since the log lies partly in a stream, only a part of the section is exposed. Fig. 2 shows a small part of a section with pockets in various stages.

Plate XI. Tangential section of Redwood log, showing the decayed wood in long pockets.

INSECT ENEMIES OF THE REDWOOD.

By A. D. Hopkins,
In Charge of Forest Insect Investigations, Division of Entomology.

In 1881 Mr. Henry Edwards described a pitch worm as very destructive to *Sequoia sempervirens.*[a] In 1899 the writer found two species of bark beetles living in the bark of recently felled trees.[b] In 1900 the Division of Entomology obtained information from Mr. J. E. Norton, through a lumber firm in San Francisco, indicating that Redwood lumber was immune from attack by termites, or white ants;[c] and this was verified by experiments conducted in the Philippine Islands by Mr. D. N. McChesney, as reported by Capt. George P. Ahern, Chief of the Philippine Forestry Bureau.[d]

This embraces about all that has been published relating to Redwood insects.

These insects and their work may be described in more detail as follows, the small type indicating information from other authors and ordinary type that based on the writer's observations, whether previously published or not:

THE SEQUOIA ÆGERINIAN, OR REDWOOD PITCH WORM.

(*Vespamima sequoiæ* Hy. Edw.)

This relative of the common peach-tree borer is described by Henry Edwards[a] and other writers[e] as very destructive to Redwood.

Mr. Beutemüller says:

According to Hy. Edwards this species is devastating the pine forests in Mendocino County, California, and is particularly destructive to the Big Tree (*Sequoia sempervirens*), *Pinus ponderosus*, and *Pinus lambertiana*. The eggs are laid in the axils of the branches, the young caterpillar boring in a tortuous manner about its retreat, thus diverting the flow of sap and causing large resinous nodules to form at the place of its workings. These nodules gradually harden, the branch then dies, and the tree at last succumbs to its insignificant enemies. Hundreds of fine trees in the forests of the region are to be seen in various stages of decay. The moths make their appearance in June and July, during which period the eggs are deposited. The

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[a] Papilio, vol. i (1881), p. 181; also Bul. U. S. Ent. Comm. No. 7, Appendix.

[b] Bul. 31, N. S., Div. Ent., U. S. Dept. Agr., pp. 7, 19, 20.

[c] Bul. 30, N. S., pp. 95, 96.

[d] As quoted in Bul. 33, Bur. Forestry, p. 20.

[e] Beutemüller, Am. Mus. Nat. Hist., vol. i, part vii, pp. 263, 264.

larvæ begin to form their cocoons in December and January, being an evidence that the insect is double brooded. The larvæ when fully grown line the channel in the resinous nodules with silk, forming a sort of cocoon, in which they transform to pupæ.

This insect was observed by the writer in September, 1902, in the vicinity of Del Monte, Cal., where it occurred in the matured larval stage in large masses of pitch on the trunks of living Monterey Pine. According to information from Mr. Lee, the gardener in charge of the Del Monte grounds, it does considerable damage to the tree.

The work of probably the same insect was also observed in the same grounds on Lawson's Cypress, causing deformities on the main trunk and branches.

REMEDY.

In comparatively small areas it would not be difficult to dig the worms out of the pitch with a knife during the fall and winter months. This would serve to greatly reduce their numbers and to prevent serious depredations in future. In the case of larger areas of forest trees there is, so far as known, no practical remedy.

CEDAR BARK-BEETLES.

There is a certain class or genus of bark-boring beetles which, so far as has been determined in different countries, inhabits only the cedar and cedar-like trees. Owing to this habit they may properly be termed cedar bark beetles. They belong to the order Coleoptera, family Scolytidæ, and genus Phlœosinus. Two species of this genus were found by the writer in living and partly living bark of recently felled Redwoods near Guerneville, Cal., in April, 1899.

The Redwood Bark-Beetle.

(*Phlœosinus sequoiæ* Hopk. MSS.)

This is a common species, which heretofore has been confused with a much less common one described by Dr. Le Conte under the name *cristatus*. It is a medium-sized, stout, black beetle (fig. 1), the male and female of which bore through the outer bark and excavate long, nearly straight burrows or galleries through the inner living or dying bark and surface of the wood, as shown in the illustration, Plate XII. The eggs are closely placed along each side of the gallery in little notches excavated for the purpose. These soon hatch into minute white grubs, which immediately commence to feed upon the inner layers of bark and outer layers of wood. They continue to feed thus, extending meanwhile their food burrows, and increase in size until they attain their full growth as grubs (larvæ). Then they enter the wood for a short distance and excavate a cavity or kind of cell, in which they change to the inactive or pupal stage. Here they remain

until their legs and wings are fully developed, when, as fully matured adults, they bore their way out through the wood and bark, producing the shot-hole condition, as shown in the illustration.

It is known that the Redwood bark-beetle flies early in April and attacks the living bark of recently-felled trees, but as yet we have no positive evidence that it attacks standing living trees. The fact, however, that a near relative, the Lawson's Cypress bark-beetle, will attack and kill trees, indicates that under specially favorable conditions this species may do likewise. Therefore any unhealthy condition of the young or old trees in which the leaves toward the top turn yellow and reddish brown should be examined for traces of the beetle's work in the bark and at the base of living twigs.

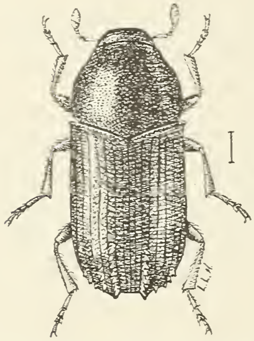

Fig. 1.—The Redwood bark beetle: adult—enlarged (original).

REMEDY.

If it should be found that this beetle is attacking living trees, its known habit of infesting recently-felled trees suggests that it might easily be controlled by cutting and barking all infested trees between the 1st of September and the 1st of December, and by providing a few trap trees to attract those beetles that escape. This may be accomplished by felling a few trees in December. Then after the adults have entered the bark in the spring and the larvæ (grubs) are about half-grown, or before they enter the surface of the wood, if the bark is stripped from all the infested parts of the trunk and larger branches, the broods will be destroyed. It will not be necessary to burn the bark thus removed, because the drying of the inner surface will kill the young stages, while some of the natural enemies of the beetle which would otherwise be destroyed by burning might survive to be of service in reducing the numbers of those which are not attracted to the trap trees or which breed in the standing timber. The tops and smaller branches, which can not conveniently be barked, should be burned, but they should first be left until the broods are nearly developed, in order that the parasites and other natural enemies may have time to develop and emerge to continue their good work. It would be best if this material were burned just before the beetles begin to emerge.

The life history of the Redwood bark-beetle has not been worked out, but the insect is probably double-brooded, the first brood emerging about the middle of summer and the other the following spring. If this is true, it is of the greatest importance to protect, so far as possible, the natural enemies of the first brood, in order that they may continue their depredations on the second brood.

Evidence was found at Guerneville, in the vacant brood galleries in bark that had been infested the previous summer, that many of the broods had been destroyed by minute wasp-like parasites and predaceous enemies. It is probable that the natural enemies of other species of the same genus will attack it, especially those of the Lawson's Cypress bark-beetle.

Lawson's Cypress Bark-Beetle.

(*Phlœosinus cupressi* Hopk. MSS.)

This is the other species found by the writer in Redwood at Guerneville, Cal. It was also found, about the same time, in a recently dead Monterey Cypress in Golden Gate Park, and in a small, dying Japanese Cypress[a] in the University grounds at Berkeley.

The general character of this beetle (fig. 2) and of its work is similar to that of the preceding beetle, except that it is a smaller, less shining insect, and that the larvæ do not enter the surface of the wood to change to the adult, but undergo their transformation in their burrows in the inner bark.

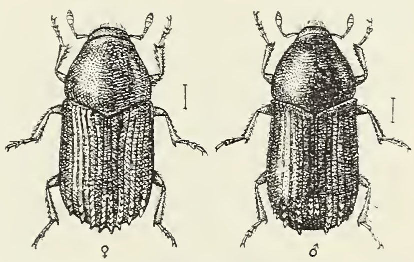

Fig. 2.—The Lawson's Cypress bark-beetle: adults, male and female (original).

The adult's habit of attacking and killing trees and of feeding on the bark of living twigs is a characteristic which has not been observed in any other species of the genus. Recently an article relating to this insect was published by Mr. Carroll Fowler,[b] under the above common name and the technical name *Phlœosinus punctatus* Lec.[c] Mr. Fowler's account of this beetle and its destructive work is as follows:

During the past year our attention has been repeatedly brought to the sickly condition of many of our Lawson's Cypress trees. This is one of our common and most handsome ornamental trees, and therefore the way in which they are dying is a matter of no small concern to many parties.

The first indication one has that the tree is diseased is in the unhealthy appearance of the upper leaves. These turn brown and die, and gradually those below take on a similar appearance, until they are all killed. If the trunk and branches are examined, it will be noticed that they are thickly punctured with small holes. Then if some of the bark is cut, it will be found to be dead in many places, especially near the top of the tree, not infrequently extending entirely across the branch. There will also be noticed small burrows just under the surface, and if it is in the winter there may usually be found at one end of each burrow a small white grub or dark-

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[a] Identified by Professor Davy as *Cryptomeria*.

[b] Rept. Univ. of Cal. Agric. Exp. Sta., 1898–1901, Part I, pp. 80, 81.

[c] The writer has examined the specimens on which this identification was based, and finds that it is quite different from *P. punctatus*, a common enemy of the Giant and other Western cedars.

brown beetle. This beetle is one of the engraver beetles, so called on account of the appearance of the system of burrows. The central tunnel is made in the sapwood by the mother beetle, which deposits eggs at frequent intervals. The larvae hatching from these eggs bore off at right angles. When the beetles are numerous the trees are frequently encircled, so that the food supply is cut off. The attack is usually begun at the top of the tree, and extends downward from year to year.

This family of beetles generally attacks trees that are not in a very healthy condition, although when they become very numerous they take to healthy trees. Such has proven to be the case with the Lawson Cypress beetle. Those trees which have suffered most severely from drought lately have been most severely injured by the pest, while those in the same locality which have been kept thrifty are in many instances almost free.

After these borers have once gotten into a tree there is no way in which they can be killed without injury to the tree. Where the attack is severe the trees should be cut down and burned during the winter while the insects are in their burrows. They begin to eat their way out as early as March, although some appear much later; hence the destruction should be done earlier than this. Trees only slightly affected need not be destroyed, since by fertilization with Chile saltpeter and frequent watering they may be gotten into such a healthy condition as to withstand, and in a measure resist, attack. Professor Hilgard has by this means saved some of his trees, which were beginning to show marked signs of injury. Prompt measures should be taken against the insect, not only to save the trees attacked, but also to prevent the numbers from becoming so great as to cause them to spread to healthy trees.

Dr. Hilgard informs the writer that his experiments with Chile saltpeter were very successful indeed, and that he believes little harm would result from the attack of this insect if the trees were kept in a healthy, vigorous condition.

Early in September of this year the writer had an opportunity to make some additional observations on the habits of this beetle at Del Monte and in the famous Monterey Cypress grove at Cypress Point, Cal. These observations indicate quite clearly that the Monterey Cypress is the original food plant, and that the common use of this tree for hedges and ornament in private grounds and parks throughout western California has enabled the beetle to extend its range from its original restricted home, and thus to acquire the habit of attacking other species of Cypress and the Redwood. This change of habit and extended range of distribution, as has been demonstrated by many of our worst insect pests which have come from other countries and other sections of our own country, involves variation in normal habit, and even in structure, which renders a species that is comparatively harmless in its original home most destructive under the influence of new environments.

An examination of the Cypress grove showed no sign that this beetle had attacked standing trees, although it was found to be exceedingly common in the bark of broken branches and storm-felled trees. The natural enemies of the broods occurred in great numbers, and up to the date of writing the number of adult parasites which have emerged from sections of branches placed in breeding jars has been exceedingly large.

An examination of Lawson's Cypress, which had been transplanted in the park at Del Monte, showed that the Lawson's Cypress bark-beetle has the common habit of boring into the living bark at the base of perfectly healthy twigs (fig. 3, *a*). It was also found that this injury would often result in the death of the lateral and deformity of the central twigs (fig. 3, *b*), while in many cases the wound would be covered with gum (fig. 3, *c*) and heal without any serious harm. This is conclusive evidence that the beetle attacks healthy plant tissue of the Lawson's Cypress. This was further verified by specimens of

FIG. 3.—Work of the Lawson's Cypress bark-beetle in twigs of living trees: *a*, burrows at base of twig; *b*, *b*, wounds covered with gum; *c*, deformed twig; *d*, wound where twig has died and fallen (original).

wood from a Lawson's Cypress said to have been killed by the beetle, which were kindly submitted to the writer by Professor Woodworth, entomologist of the California experimental station at Berkeley. An examination of this specimen showed in the healed-over wounds made by the beetles that at least two successive annual attacks on the living bark had been made before the tree died. Nevertheless, the annual rings of wood showed nearly a normal growth and indicated an otherwise healthy condition up to the year in which the tree died. It would therefore appear that while the insect breeds normally only in the felled or otherwise injured trees, it is capable of attacking healthy

trees and of causing the death of transplanted Monterey, Lawson's, and other species of Cypress. The fact that it has been found in Redwood renders it an enemy of especial interest in this connection, and one which should be carefully watched.

Recent observations by the writer near Mill Valley, California, and along the railroad leading up the western slope of Tamalpais, of an unhealthy condition of the tops of second-growth Redwood, suggest that this heretofore unnoticed trouble may be due to the work of the Lawson's Cypress, or the Redwood, bark-beetle. It is reported that much of the Lawson's Cypress in the country mentioned has recently died. If this has been caused by the Lawson's Cypress bark-beetle, as it probably has, the same insect may be to blame for the diseased condition of the Redwood.

REMEDY.

The maintenance of a healthy, vigorous growth by the application of Chile saltpeter or other fertilizers which may hereafter be found especially useful for this purpose, in addition to irrigation during severe drought, as suggested by Dr. Hilgard, is undoubtedly a most excellent provision against attack, and wherever practicable should be adopted. Otherwise, where forests of Redwood or other trees are infested or threatened by an invasion of this enemy, the recommendations for cutting and barking infested trees and for providing trap trees for the control of the Redwood bark-beetle should be adopted.

PARASITES.

The parasite reared from Monterey Cypress bark infested by this beetle was submitted to Mr. William H. Ashmead, the recognized authority on this class of insects, who found that it is a Cecidostiba sp. The abundance of this parasite, in what is evidently the normal home of the beetle, suggests that this species may very profitably be introduced into localities where the beetle is carrying on its destructive work on the same or other trees. This could easily be accomplished if medium-sized branches were cut from trees in the original grove during February, left there until thoroughly infested with broods of the beetles and their parasites, then, just before time for the parasites to emerge, cut into sections about 1 foot long and taken without delay to the desired localities and there placed among the tops of the felled trees. The parasites would then emerge and readily find their victims. Any efforts of this kind, however, should be made by an entomologist, or under his supervision.

The Monterey Cypress Bark-Beetle.

(*Phlœosinus cristatus* Lec.)

This is another Cedar bark-beetle which is closely allied to the preceding, and is the true *cristatus*, with which several other species have heretofore been confused.

In February, 1893, specimens of this insect and its work were sent to the Division of Entomology by Mr. J. Dickee, Riverside, Cal., with a statement that it was doing great damage to Cypress hedges in Contra Costa County, Cal. Nothing further is known of its habits, but it is possible that it may also attack the Redwood. (Fig. 4.)

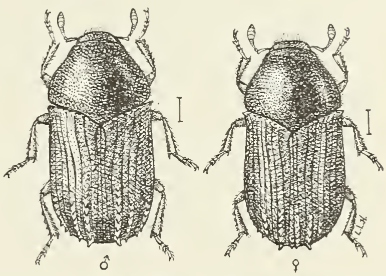

FIG. 4.—The Monterey Cypress bark-beetle: adults, male and female—enlarged (original).

The other species of insects found by the writer in Guerneville, Cal., in Redwood, may be briefly mentioned as follows:

Phymatodes decussatus Lec. This long-horn beetle (Cerambycid) was reared from a section of a small dead tree, and the larva of probably the same insect was found in the bark of a dying tree.

Callidium janthinum Lec. A dead adult of this well-known enemy of Cedar was found on the bark of a log, where it had evidently bred.

IMMUNITY OF REDWOOD FROM ATTACK BY TERMITES OR WHITE ANTS.

Probably the first officially published record of the relation of Redwood to the wood-destroying termites of tropical regions was that which appeared in Bulletin No. 30, new series, Division of Entomology, U. S. Department of Agriculture (1901), p. 95. This reference is quoted as follows:

December 13, 1900, we received a communication through a firm of lumber merchants of San Francisco, Cal., which appears to indicate that the California Redwood lumber is immune to the attack of white ants or termites. Through the firm in question we received a letter from Mr. J. E. Norton, dated December 4, relating to the resistance of this wood to the so-called Manila white ant of Annia. His letter is in substance as follows:

"In the latter part of 1898 I secured from a transport a piece of Redwood lumber in a yard at Manila. The spot was damp, and various pieces of timber all around showed evidence of the existence of the ant in abundance. This piece lay undisturbed for a period of five or six months, and when examined was found as sound as when put there, not having been attacked by any insects. The Chinaman, owner of the lumber yard, was still doubtful and undertook to get it eaten by putting it in different places under different conditions, such as on top of pieces already inhabited, between boards, and underneath piles, and finally, after three months, put the sample on exhibition in his office with the following placard: 'Madera Colorado de California, no se comen Annai.'

"The quartermaster's lumber yard had piled for some four or five months a quantity of Redwood, which upon my departure in October was still free from ants.

"John MacLeod, of Manila, has a room in one of his houses finished in Redwood, constructed over fifteen years ago, and to this day three-fourths of the original amount remains still in good condition, one-fourth having been worn out and replaced by other lumber."

Reference is made in Bulletin No. 33 of the Bureau of Forestry (p. 20) to certain experiments conducted in Manila, P. I., by Mr. D. N. McChesney, as reported by Capt. George P. Ahern, Chief of the Philippine Forestry Bureau, in which it would appear that Redwood, Incense Cedar, and Western Hemlock were not attacked, while Douglas Spruce, Bull Pine, and Engelmann Spruce were seriously injured.

The reader is referred to Circular No. 50, second series, Division of Entomology, U. S. Department of Agriculture, by C. L. Marlatt, for a general description of white ants, their habits and work.

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